RECORDS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

VOL. XV.

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CONTENTS.

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Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1881.

The work done or published during the past year involves some considerable changes in the mapping and grouping of Indian rocks as hitherto set forth. These changes are duly noticed in the following report.

After closing his work in the Godávari region, Mr. King took up as yet unsurveyed country in Travancore. The neighbourhood of Quilon has for many years been known through the observations of General Cullen, published by Dr. Carter in his Summary of the Geology of India (1853), as having yielded a limestone containing eocene fossils, and we have long been anxious to bring this rock into connection with other tertiary beds of uncertain horizon in the coastal region of the peninsula. In this we have been disappointed of any positive result, beyond the fact of super-position, for Mr. King's most diligent search failed to bring to light any trace of General Cullen's limestone. The point had been independently investigated by the Public Works Department in searching for lime, but with the same negative result. General Cullen's statements are, however, too circumstantial to be called in question, and we must only suppose that all the rock available at the outcrop, which was at the very base of the cliff-section, had been removed, thus favouring the concealment of the bed. The overlying deposits of ferruginous sandstone and clays with lignite (or rather fossil wood) Mr. King describes[1] as the Warkilli beds, correlating them with the Cuddalore sandstone of the Coromandel Coast. They only occur for a length of about 20 miles, from a little north of Quilon to Anjengo on the south.

Southern India: Travancore. Mr King.

At the particular request of the Travancore Durbar, Mr. King made an examination of the tract of gneissic upland in which auriferous rocks were reported

[1] The paper will be published in the Records for May next.

to occur. The outcrops in question turned out to be bedded quartzite and not true reef rock; there seemed to be no prospect of a fruitful gold-field.

Godavari.

The publication of Mr. King's description of the Pranhita-Godávari area (Memoirs, Vol. XVIII, pt. 3), has brought to a crisis some doubts and discrepancies that have been long impending regarding the older rocks of the peninsula. It was duly pointed out in the Manual (pp. 3 and 55) that the division of the separated rocks of transitional character into an upper and a lower series was a provisional compromise, until connected surveys should declare what the true relations might be, the only immediate test—the relative ages of the gneissic rocks adjoining each area—not being available. In the same connection it was noted (*l. c.*, p. 70) that the categorically marked separation of the lower Vindhyan from the upper transition rocks, as then constituted, was especially arbitrary and precarious. As a matter of course, whatever discrepancies there might be were bound to come into collision in the then little known middle ground in the Máhánadi and Godávari basins, as was pointed out at pages 75 and 76 of the Manual. Mr. King's survey of the latter area seems to have brought observation sufficiently close for a settlement of the main question at issue. In his statement of the case (*l. c.*, p. 73), there is some confusion between a local difficulty and the principal point of classification. In the Máhánadi basin, and again on the Pemganga, which belongs to the Pranhita-Godávari basin, there was a difference of opinion as to the relative ages of the shales and limestones occupying the low ground and certain quartzites resting on the gneiss of adjoining uplands; and this minor question remains still in doubt. When the Manual was published, the data for the general question had not got clear of this minor one; but now Mr. King has extended his observations to the shales of the Pemganga and, for the first time, the major question is clearly at issue. These shales had been classed as lower Vindhyan. Mr. King decides that they are Kadapah, and his statement of the case would be understood to imply that the other position must be wrong. It seems to me that the simpler and truer adjustment is to accept both as right. I do not question Mr. King's identification, which is based on a connected survey from the Kadapah field; but I see no reason to reject the independent determination of the Máhánadi and Pemganga beds as lower Vindhyan: so the obvious reconciliation is to conclude that the Kadapahs also are lower Vindhyan. There are numerous collateral points in support of such a decision, but they cannot be detailed here; and the further questions raised by it are not seriously in the way—such as, whether the rock-groups in Southern India (the Karnul and Bhima series), hitherto ranked as lower Vindhyan, must now be classed as upper Vindhyan. The intelligent student of the Manual will, on the whole, accept this new reading as a relief.

Comorin:
Mr. Foote.

On his return from furlough, Mr. Foote took up work again at Mádura, and made a traverse thence to Cape Comorin along the junction of the gneiss and the coastal alluvium. The formations which, to the north, intervene in this position seem to be almost wholly wanting here to near Comorin, where representatives of the Cuddalore sandstone again appear and seem to extend some little way westwards towards the tertiary deposits of Travancore. About Comorin there were also observed at least two banks of marine beds, one of them at about 100 feet over present sea level; they consist of sands with calcareous induration, and are full of marine shells of living species. Mr. Foote remarks that he has not found a single trappean intrusion in the gneiss south of Trichinopoly, a circumstance in strong contrast with the profusion of eruptive dykes in the adjoining gneiss of Salem and Arcot.

RAJPUTANA. *Mr. Hacket.*

As mentioned in last Annual Report, the publication of the Rájputána work had to be postponed until some doubts, suggested by the most recent observations, had been cleared up. This was effected during the past season, and the result published in Mr. Hacket's paper in the last number of the Records (Vol. XIV, part 4), with an outline map of an immense stretch of country, from Delhi to Erinpura and Mandsaur. The early work in the northern part of this ground was described in the Records for 1877 (Vol. X, p. 84), and the account there given of the Arvali rocks is that presented in the Manual (Chapter II). Already, in the following Annual Report (February 1879, Records, Vol. XII, p. 5) considerable alterations were necessitated by subsequent field work: the groups of distinguishable deposits, all more or less metamorphic, brought together under the title Arvali series, were reduced in number by a clearer interpretation of the sections, and one of the lower members was identified with some rocks outside this metamorphic area and previously described as the Gwalior series, resting quite undisturbed and unaltered on the gneiss of Bundelkhand. The interesting fact was thus established that the gneissic metamorphism of the Arvali region was of immensely later date than that of other portions of the peninsular area.

A similar change has now to be introduced regarding the upper member of the original Arvali series, the great quartzite deposits of the Biána and Alwar hills, and of Delhi, which Mr. Hacket now proposes to distinguish separately as the Delhi series. In making a preliminary traverse of the country northwards from Bág in the Narbada valley, in 1865-66 (Records, Vol. I, p. 69), I came upon certain quartzite sandstones at Mandsaur with underlying shales, very little altered or disturbed, and both most nearly resembling the familiar upper Vindhyan types; and they have since passed as such in the Manual and its map. The overlying shales and limestone well seen north of Nimach (Neemuch), and the sandstone of Chitor Hill I took to represent the Bánrer (Bundair) stage of the upper Vindhyan series. Had my route continued north-eastward across the Vindhyan plateau, I should have discovered my mistake by finding the higher upper Vindhyan stages still in front of me; but no suspicion of error was suggested. Mr. Hacket's continuous survey from the north has satisfied him that the Chitor rock is the Kaimur sandstone, the lowest member of the upper Vindhyan series; and that the limestone of the low ground to the west is the lower Vindhyan (Rotás) limestone. Although a slight unconformity is found between these beds and the Mandsaur sandstone, it is scarcely greater in appearance than may be found between the upper Vindhyan groups, where they overlap each other on the borders of their typical area; and so the Mandsaur rock might have been provisionally entered as a member of the lower Vindhyan series, but for a further discovery: Mr. Hacket shown good ground for asserting that the Mandsaur sandstone passes northwards into connexion with quartzites of the Arvali area that are more or less continuously traceable through Eastern Rájputána into the hills of Alwar and Delhi. This fact would necessitate a prodigious significance for the unconformity west of Nimach, for the Delhi series has partaken fully in the Arvali disturbance; while the whole Vindhyan system dates from an age when the Arvali mountains had already undergone great denudation. Geologists will appreciate what an interval that implies.

Collateral facts support these observations. The conspicuous erosion-unconformity in the Gwalior area between the Vindhyans and the Gwalior rocks, which represent the lower (Arvali) series, contrasts appropriately with the less apparent unconformity of Vindhyans on the Mandsaur rock, which represents the higher (Delhi) series of the Arvali region. Further, the condition of the Delhi rocks at Mandsaur is accounted for by the fact that to the west of them there occurs a mass of gneiss, which is presumably identifiable with that of Bundelkhand, whereby they were protected from the crushing and metamorphism that affected the Arvali region proper.

These modifications of our rock-grouping have a further significance with reference to the changes already noticed in connexion with the Godávari region. Hitherto the Gwalior rocks have been provisionally correlated with the Kadapah series, as upper transition. The Kadapah rocks having now been brought up to the lower Vindhyan horizon, and the Gwalior beds put down immeasurably below that horizon, the separation of the two is very great, and the Gwalior rocks must take approximate rank in the Survey classification with the Bijáwars, their affinities with which have been duly noticed before (Manual, p. 56); while the Delhi quartzites become the highest member of the transition series as now distinguished.

There is one more change in the Arvali region to be mentioned. From a small and very local occurrence of a felsitic-rock in the middle of the range, the trappean rocks described by Mr. Blanford as the Maláni group had been (Records, XIII, p. 4) doubtfully placed by Mr. Hacket in the Arvali series. His extended examination of these rocks south of Jodhpur has shown such a position to be untenable, as the Maláni beds exhibit very little disturbance, and rest upon contorted Arvali strata. According to this relation, their apparent horizon would be lower Vindhyan.

As mentioned in last Annual Report, some simple field work was marked out for Sub Assistant Kishen Singh, in extension of Mr. Hacket's previous work on the Vindhyan rocks in the Gwalior territories. From his maps and report there seems much reason to be satisfied with his work on the score of care and industry, for it is impossible, under existing circumstances, as I have often explained, and without extravagant waste of our very limited power of qualified observers, to arrange for the inspection of detached work. At the same time there is ample evidence of such radical defects as were to be anticipated: in the barren accumulation of simple details of stratification, with ambitious but weak attempts at speculation upon remote theoretical considerations quite beyond the scope of the work in hand, and that can only be profitably undertaken by one who has in some degree mastered the subject; and withal there was a conspicuous failure to understand the obvious condition—that ordinary geological maps are meant to represent the formation next below the soil. Some improvement may be expected with experience.

SOUTH REWAH: GONDWANA. *Mr. Hughes.*

Mr. Hughes' work during the past season was confined to the coal fields on the southern outcrop of the South Rewah basin. A notice of results was published in the Records for November. Although the prospects of coal are not so promising as may have been hoped for, some good seams have been traced, but unfortunately they are the most distant from any existing line of railway. Since taking the field for the present season, Mr. Hughes has marked sites for trial borings he has recommended to the Rewah Durbar, in the small Umria field, the nearest to the Jabalpur railway.

Sub-Assistant Hira Lal worked with Mr. Hughes, and did good service in hunting up coal outcrops and main boundaries.

Dr. Feistmantel.

Dr. Feistmantel was able to devote a few weeks during the field season to visit some of the coal-fields in the Upper Damuda valley. He has made considerable additions to our collection of fossils from that ground, many from new localities. It becomes more and more evident that in the central basins of the Gondwána system, the possibility of discriminating horizons in the masses of homogeneous deposits there prevailing will depend almost entirely upon the scanty fossil evidence; so it is more than ever important to obtain a closer knowledge of the distribution of the flora in ground where the stratigraphical sequence is otherwise discernible.

NARBADA: CRETACEOUS: *Mr. Bose.*

Mr. Bose has submitted a very promising progress report of his season's work on the cretaceous rocks of the Narbada valley, generally known as the Bág beds. They are remarkable as being the only fossiliferous marine deposits beyond (inside) the coastal region of the peninsula. An excellent preliminary sketch of these rocks was given in 1869 (Mem., Vol. VI., pt. 3) by Mr. W. T. Blanford in his general description of the Tápti and Narbada valleys, with a map on a very small scale; wherein the whole are grouped from the small fossil evidence then existing as of middle cretaceous (cenomanian) age, on about the horizon of the Utatúr beds of Southern India, and as probably, in part, representing the freshwater infra-trappean (Lameta) beds of more midland districts. Mr. Bose proposes to give an immensely extended range to the series; besides finding the Lameta beds distinctively in the marine area, he gets fossil evidence to suggest that the three limestones of Mr. Blanford's classification (Manual, p. 294), may represent the divisions of the cretaceous series of Southern India, and that the underlying sandstone may be lower cretaceous (neocomian). If these conjectures should be established, a considerable lift will be given to the presumed age of the Deccan traps. Under these circumstances Mr. Bose has judiciously deferred giving any publication of his work until he can present it with more confidence in his results.

Mr. Fedden resumed his survey of Kattywar where he had left off in 1879, and mapped a large additional area. Deccan trap is the greatly prevailing rock. A small area of the newer tertiary beds on the east coast was examined, and some patches of jurassic (Umia) beds on the north; but nothing of importance was noted.

KATTYWAR
Mr. Fedden.

During the past field season Mr. Lydekker rounded off the western limits of his work in the Kashmir territories, in the lower Kishanganga valley, joining his lines with those of Mr. Wynne in Hazára. These observations have removed whatever nominal doubt remained upon a small point of geographical interest. Certain geographers have insisted upon classing some of the great trans-Indus peaks with the Himalayan range proper. The intrinsic objections to this arrangement have been duly pointed out by the Geological Survey, and they are now fully ratified by Mr. Lydekker's work, showing that the Pir Panjál and Zánskár axes, which are the attenuated extensions of the great snowy range, become wholly extinct on either side of the west end of the Káshmir valley. As part of this feature, a considerable extension of the tertiary rocks of the sub-Himalayan area has been traced out: in our maps hitherto published the deep northern prolongation of this area up the valley of the Jhelam between the two confluent systems of disturbance has been stopped at Muzafirabad, near the junction of the Kishanganga with the Jhelam; Mr. Lydekker has now mapped a deep recess of these rocks reaching 20 miles further north. In this connexion Mr. Lydekker makes some inferences regarding an extensive pre-eocene Himalyan elevation: it is a conclusion that has some time since been very explicitly enunciated upon good evidence (Manual, Part II, pp. 569, 680), yet in very recent sketches of the great east-west Asiatic mountain system, of which the Himalaya is the most conspicuous member, we find it asserted that the upheaval commenced in the oligocene epoch, as has apparently been made out for the European extension of that great system of disturbance.

HIMALAYA,
KASHMIR
Mr. Lydekker.

Mr Oldham spent a profitable season in the Simla region. A good part of the time was of course expended in making acquaintance with the characters and general features of the rocks as hitherto set forth, regarding which he has made some important observations and conjectures. On the Giri he has observed some clear cases of intrusion of the syenitic trap into the middle tertiary sandstones at their junction with the older rocks. To the west of old Sirmur he notices distinct evidence of an actual creep now in progress along this boundary fault, as shown by a continuous line of depression to the south across the spurs and gullies running northwards into the Giri. Well within the Lower Himalayan area Mr. Oldham describes some masses of rock, as the red slates and quartzites of the Chakráta ridge and the purple and red shales, with pebbles derived from a neighbouring limestone, in the Maura forest north of the Karambar peak which he conjectures may be of lower tertiary (Sirmur) age. The verification of this suggestion is a point of great interest in the discussion of Himalayan history; the non-occurrence of the nummulitic (Subáthu) band at

HIMALAYA;
SIMLA REGION;
Mr. Oldham.

the base of these supposed outliers would at least show that there was great overlap towards the mountain axis, as already observed at Subáthu (Manual, pp. 533, 569). Among the Lower Himalayan rocks themselves, Mr. Oldham considers that there is a clear case in Deoban mountain of a great unconformity of the Krol limestone with the subjacent rocks. The obvious doubt in such sections is the risk of the results of extreme contortion with over-folding and sliding being taken for original relations of the masses. An observer unaccustomed to the study of 'true mountains' might well be excused for such mistakes; and the detection of them without fossil evidence would often be impossible. Any one wishing initiation to these mysteries should study Professor Heim's "Untersuchungen über den Mechanismus der Gebirgsbildung," an inspection of Plate VII of which work will suffice to remove any scruples as to the capabilities of the folded flexure in mountain structure.

It has been with much regret that I have interrupted Mr. Oldham's work after so promising a beginning; but an opportunity occurred of sending a geologist with the party proceeding to demarcate the Manipur-Burma frontier, and I could not miss so rare a chance of exploring an unknown region. Mr. Oldham volunteered for the expedition; and there being no other officer available at the time, I was glad to commission so trustworthy an observer.

HIMALAYA; KUMAON: *Mr. Griesbach.*

After his service in South Afghanistan Mr. Griesbach returned in April last to the work he had begun in the summer of 1879 in the high Himalaya of Kumaun, of which a sketch was given in Vol. XIII, pt. 2 of the Records. He has now completed the survey of that ground up to the Nepál frontier. The same great sequence of sedimentary rocks has been traced throughout, only greatly more disturbed than in the Niti section. This may be simply the approach to a middle region of maximum Himalayan disturbance, or it may indicate the proximity of a block of crystalline rock such as to the north-west breaks the continuity between the ellipsoidal basins of the fossiliferous series. Mr. Griesbach was again prevented by the vigilance of the Chinese frontier guards from making any way into Hundes; in this attempt he also experienced much obstruction and even personal violence from the people within the British border, who seem far more under the control of the Tibetan officials than of our own officers at Almora. For both these reasons he could not this year get within reach of any beds higher than the Spiti shales (Oolitic), some remnants of which were found folded in the flexures of the older formations. The natural completion of this piece of work will be its extension up to the gorge of the Sutlej, where the gneissic mass of Purgial cuts off, at least in great part, the continuity of the fossiliferous rocks, dividing the basin of Hundes from that of Spiti and Zánskár. This, it is hoped, can be accomplished next season, meanwhile arrangements are being made to reproduce effectively the admirable profile views which Mr. Griesbach's artistic skill has enabled him to figure of the grand sections displayed in these stupendous mountains.

In the lower hills Mr. Griesbach has confirmed an interesting observation, made more than 30 years ago by General Richard Strachey, of the irruption of the trappean rock of the Lower Himalaya, so extensively exhibited to the east of Naini Tál, into the tertiary sub-Himalayan sandstone on the Gola river, and its conversion thereby into a granite. It was, indeed, only provisionally that any hesitation was admitted regarding an observation by so competent a witness; but the remarkable absence of igneous rocks, whether intrusive or eruptive, in the sub-Himalayan zone throughout an immense sketch of country, even in the immediate vicinity of their extensive exhibition in contiguous rocks, as on the Biás and the Sutlej, could not but suggest doubt regarding an isolated instance, and this although upon general reasoning it was apparent that the trap of the Lower Himalaya was of tertiary age (Manual II, p. 607). Mr. Theobald, moreover, had mapped the tertiary boundary at the Gola river without detecting any eruptive contact. Mr. Griesbach, however, declares that the facts are as described by General Strachey. In this connexion Mr. Griesbach is disposed to maintain that some altered sandstones about Bhim-tál, inside the sub-Himalayan zone, are of the same age as the rocks outside the main boundary on the Gola. This is not quite equivalent to the observation recorded by Mr. Oldham in the Simla region, where the lowest tertiary sandstones are at hand. It is not yet proven that the lower tertiary beds are represented in the sub-Himalayan zone of Kumaun.

HIMALAYA; SIKKIM.

At the request of the Government of Bengal to have an opinion upon a newly opened copper locality in the Darjeeling district, Mr. Mallet was deputed to examine it. He found it to occur in the same beds and in the same manner as the ores previously described in his report on the geology of the district (Mem., Vol. XI, pt. 1). The deposit is no richer than in some of the old mines.

On the report that serviceable blocks of coal had been obtained from a seam near Tindháriá station on the Darjeeling tram railway, I visited the place to satisfy myself upon a question of so much importance. I found the seam to be one of those marked on Mr. Mallet's map, and the whole condition of the case to be exactly as described by him in the report just quoted. These were, no doubt, originally strong seams of good coal; but, owing to the compression undergone during the upheaval of the Himalaya, the coal and its measures have been so shattered that the question of profitable extraction is a very precarious one. There is, I consider, very little hope of finding coal in a directly serviceable state anywhere in these measures; so that complete arrangements for the conversion of the dust coal into bricks must be a preliminary condition of the experiment. Then as to the mining: there is, I believe, a sufficient quantity of the coal in the ground, and although no doubt often squeezed out and nipped, it would not be very difficult of extraction but for the shattered condition of the surrounding rocks. These are not, like the older rocks of the higher mountains in which the copper occurs, consolidated by crystalline metamorphism, but are still in the slaty state and shivered to splinters to the very core, so that every foot of drift or gallery would have to be protected in the most solid, and of course costly, manner by posts and boarding. This was the experience gained by the short trial drift made on the outcrop south-west of Tindháriá (see Records, Vol. X., pt. 3).

THE BOLOGNA CONGRESS: *Mr. Blanford.*

In December 1880 I applied for official sanction to attend the international congress of geologists to be held at Bologna in September 1880; formal permission was received in May 1881. To my great disappointment, as the time drew near, the unexpected delay of work that could not be left in other hands made it impossible for me to avail myself of this permission, so I requested that Mr. W. T. Blanford, who was then on leave in Europe, might be deputed in my stead, and this was granted. Mr. Blanford's report of what was effected at the congress is published in the current number of the Records; it is a much more complete account than any I have yet seen in print. Where a definite result was possible—in the simpler matter of nomenclature—we may perhaps be satisfied with what was accomplished, though it certainly is not what would have been arrived at by a plebiscite, or a fairly representative assembly, of geologists. At least one stiff-necked nation seems to have declined co-operation, or to have held to its own, for which it will no doubt pay the natural penalty of isolation; but we may hope that the English-speaking peoples will adopt the suggestions agreed to, even though it may involve a temporary wrenching of the vernacular sense of current terms; the advantage of uniformity of speech will well repay the struggle.

It would be hard to complain of failure where success was impossible, as is pretty much the case with a proposal to fix an universal scale of colours as assigned to any existing scale of systems. Stratified rocks will everywhere be naturally divisible into systems, series, stages, and strata; but these cannot correspond in different great sections of the earth. It would be as reasonable to attempt to unify the periods of Chinese, Egyptian, and Peruvian history as to unify the geological histories of the three great continents. Some general principles of approximation might indeed be suggested for guidance, and such an attempt was to have been expected from a nominally universal congress. This was verbally implied in the programme laid down for Bologna; and, in view of it, I submitted a test case (Records, XIV, 4) for the consideration of that congress, as being the main difficulty from the Indian point of view. The congress did not, however, get within sight of this question, but lapsed into the discussion of a scale of colours for the scale of European systems. It is no doubt most easy to account for this event, subjectively and objectively: it is a truly vexatious result of nationality that the maps of adjacent patches of the western promontory of Asia should have rocks of the same age represented under contrasting colours. The adjustment of this local barbarism seems to be the necessary preliminary of approach to the wider question, so we must fain be content with this proposal for the present.

Mining Records.—A fair start has been made in the preliminary system of collecting mining records, as announced in the last annual report. Fifty-three plans of coal mines in Bengal have been received from the following owners (in order of date): Messrs. Apcar, 12; Equitable Coal Company, 2; East India Railway Company, 6; Bengal Coal Company, 11; New Beerbhoom Coal Company, 5; Burrakur Coal Company, 1; thirteen different native proprietors, 16.

Publications.—The most generally useful publication during the year was the 3rd volume, or part, of the Manual, relating to economic geology, by Mr. V. Ball. It gives a complete classified summary of all information collected by the Survey, or independently published, regarding the distribution of useful minerals in India. The area is so large that details of any particular locality had to be greatly curtailed, but careful reference is given to the original authorities.

Three parts, forming Volume XVIII, of the Memoirs, were issued during the year. The first is Mr. Griesbach's description with numerous illustrations of the section between India and Girishk, in Southern Afghanistan. Part 2 is a description of a large area in Mánbhum and Singhbhum, by Mr. Ball, from a survey he made several years ago. The third part is Mr. King's Memoir on the Gondwána basin of the lower Godávari. This is an important district, as possibly containing a considerable supply of coal and the only one within comparatively easy reach of Southern India. From this point of view the geological indications are not so detailed as would be desirable: it is a very wild country, and for large parts of it maps on an adequate scale for close work were not available; the rocks are, moreover, very unfavourably disposed for observation, the most important ground, where the coal measures or the strata next them might be exposed, being very extensively covered by superficial deposits.

The Volume (XIV) of Records for the year is the fullest yet published, containing 24 papers of varied interest relating to the Geology of India, with numerous maps and plates.

Of the Palæontologia Indica three parts appeared during the year. Dr. Feistmantel issued two parts (86 pages of text and 35 plates), completing the 'Flora of the Gondwána System,' in three volumes. It is most satisfactory to have this complete foundation laid for the study of this series of fossils, representing the most important rock system of peninsular India. There is now a safe guide at hand for exploring any horizon in these deposits; that we have still much to learn regarding the Gondwána flora will, however, be readily understood when we recollect that the detailed survey of the two principal central basins has only begun. In the concluding remarks of his 3rd volume, Dr. Feistmantel seems to have worked out a satisfactory reconciliation of the diverse opinions regarding the correlation of the plant-bearing series of India and Australia.

The third part of Dr. Waagen's work on the fossils of the Salt-range, containing the *Pelecypoda* of the Productus-limestone series, was issued during the year. This is the first marine fauna of the older formations in this part of the world that has been worked out from anything like adequate materials; and as the work advances it becomes more and more apparent how difficult it will be to place it in any one of the would-be standard periods.

Museum.—In every branch of the museum due progress has been made in arrangement and the addition of new specimens. Dr. Feistmantel issued a 'Popular Guide' to the general palæontological collections, uniform with those already published. The numerous series of useful mineral substances and their products mentioned in last year's report have been laid out by Mr. Mallet, and make a very instructive exhibition.

Library.—One thousand six hundred and seventy-two volumes, or parts of volumes, have been received during the year; 970 by donation or exchange and 702 by purchase. A catalogue is nearly ready for publication.

Personnel.—Mr. Blanford returned to duty in England on the 22nd of August in connection with the Bologna Congress, and arrived in India on the 25th of October. He has taken up work on the north-west frontier in extension of his former work in Sind. Mr. Theobald went on furlough in March, and has since taken his pension after a service of 32 years. In so long a period he has of course done work in many parts of India; the report on Pegu is his principal contribution to the Survey Memoirs. As an enthusiastic naturalist, Mr. Theobald made good use of his opportunities; especially in the branches of land and fresh-water shells, and the *Reptilia*, he has left his mark in the annals of Indian zoology. He takes with him the hearty good wishes of all his colleagues on the Survey. Mr. King went on furlough on the 10th of May. Mr. Wynne has been absent for the whole year, having had to get an extension of his sick-leave. Mr. Mallet was absent on privilege leave from 10th to 28th of October. Mr. Ball left India on the 14th of October, having retired from the service. Although still in sound health, he was reluctantly compelled to take this step on account of a local weakness that disabled him from following any longer the hard pedestrian labours of field geology. He has, however, reaped a fair reward for the good work he has done in India, having had the honour of being elected to the Chair of Geology at Trinity College, Dublin, in succession to so distinguished a Professor as the Revd. Samuel Haughton. Mr. Griesbach went on privilege leave on the 21st December. Mr. Thomas Henry Digues La Touche, B.A. (Cantab), was appointed to the Survey by the Secretary of State in the room of Mr. Theobald, and joined his appointment in India on the 29th of November. I had intended him to have taken up work on the Deccan trap in the Konkan, but an urgent demand having arisen for particular information regarding coal with reference to a proposed railway to Assam through the Gáro Hills, Mr. La Touche has been sent to complete the survey of the cretaceous coal-fields in the valley of the Sumesari.

H. B. MEDLICOTT,
Superintendent, Geological Survey of India.

CALCUTTA,
The 28th of January 1882.

List of Societies and other Institutions from which Publications have been received in donation, or exchange, for the Library of the Geological Survey of India, during the year 1881.

ALBANY.—New York State Museum.
AMSTERDAM.—Netherlands Colonial Department.
BATAVIA.—Batavian Society of Arts and Sciences.
" Royal Natural History Society, Netherlands.
BELFAST.—Natural History Society.

BERLIN.—German Geological Society.
" Royal Prussian Academy of Sciences.
BOLOGNA.—Academy of Sciences.
" Geological and Palæontological Institute.
" International Geological Congress.
BOMBAY.—Bombay Branch Royal Asiatic Society.
" Meteorological Department, Western India.
BOSTON.—American Academy of Arts and Sciences.
" Society of Natural History.
BRESLAU.—Silesian Society of Natural History.
BRISTOL.—Bristol Museum.
" Naturalists' Society.
BRUSSELS.—Geographical Society of Belgium.
" Geological Survey of Belgium.
" Royal Academy of Sciences.
" Royal Museum of Natural History of Belgium.
BUDAPEST.—Geological Institute, Hungary.
BUFFALO.—Society of Natural Sciences.
CALCUTTA.—Agricultural and Horticultural Society.
" Asiatic Society of Bengal.
" Marine Survey.
" Meteorological Department.
" Survey of India.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CHRISTIANA.—Editorial Committee, Norwegian North Atlantic Expedition.
COPENHAGEN.—Royal Danish Academy.
DIJON.—Academy of Sciences.
DRESDEN.—Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
" Royal Irish Academy.
EDINBURGH.—Royal Scottish Society.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Philosophical Society.
GOTTINGEN.—Royal Society of Gottingen.
HALLE.—Imp. Leop. Carol. German Academy.
" Natural History Society.
LAUSANNE.—Vaudois Society of Natural Science.
LIEGE.—Geological Society of Belgium.
LISBON.—Geographical Society.
" Geological Department, Portugal.
LIVERPOOL.—Geological Society.
" Literary and Philosophical Society of Liverpool.
LONDON.—Geological Society.
" Iron and Steel Institute.
" Linnean Society.

LONDON.—Royal Asiatic Society.
" Royal Geographical Society.
" Royal Institute of Great Britain.
" Royal Society.
" Society of Arts.
" Zoological Society.
LYONS.—Museum of Natural Sciences.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
" Literary and Philosophical Society.
MANCHESTER.—Scientific Students' Association.
MELBOURNE.—Mining Department, Victoria.
" Royal Society of Victoria.
MILAN.—Italian Society of Natural Sciences.
MONTREAL.—Geological Survey of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy of Sciences.
NEUCHATEL.—Society of Natural Sciences.
NEW HAVEN.—Editors of the American Journal of Science.
NEW YORK.—American Meteorological Society.
NEW ZEALAND.—Colonial Museum and Geological Survey.
PARIS.—Geological Society of France.
" Mining Department.
" Zoological Society of France.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
" American Philosophical Society.
" Franklin Institute.
" Zoological Society.
PISA.—Society of Natural Sciences, Tuscany.
RIO DE JANEIRO.—School of Mines.
ROME.—Royal Geological Commission of Italy.
" Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
SAINT PETERSBURG.—Imperial Academy of Sciences.
SALEM, MASS.—Essex Institute.
" Peabody Academy.
SINGAPORE.—Straits Branch Royal Asiatic Society.
STOCKHOLM.—Geological Survey of Sweden.
" Royal Academy.
SYDNEY.—Department of Mines, New South Wales.
" Philosophical Society of New South Wales.
" Royal Society of New South Wales.
TURIN.—Royal Academy of Sciences.
VIENNA.—Agricultural Ministry.
" Imperial Academy of Sciences.

VIENNA.—Imperial Geological Institute.
WASHINGTON.—Department of Agriculture.
" Smithsonian Institute.
" United States Geographical Survey, west of 100th Meridian.
" United States Geological and Geographical Survey.
WELLINGTON.—Geological Survey of New Zealand.
WELLINGTON.—New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
" German Naturalists' Society.
ZURICH.—Natural History Society.
The Commissioner of Inland Customs.
" Resident, Hyderabad.
" Government of Bengal.
" " of Bombay.
" " of Madras.
" " of N.-W. Provinces and Oude.
" " Punjab.
" Chief Commissioner of Assam.
" " " of British Burmah.
" " " of Central Provinces.
" " " of Mysore.
" Superintendent of Farms, Madras.
Foreign, Forest, Home, and Revenue and Agricultural Departments.

Geology of North-West Káshmir *and* Khágán *(being sixth notice of Geology of* Káshmir *and neighbouring territories) by* R. LYDEKKER, B.A., F.Z.S., *Geological Survey of India.*

(With map and section.)

INTRODUCTORY.

The geological work accomplished by myself during the past summer has completed the preliminary examination of the rocks of the north-western part of Káshmir territory. Some additional observations have also been made on the rocks of the Pir-Panjál range, and on those in the neighbourhood of Sonamarg and the Zoji-lá: the latter observations have led to a complete re-determination of the age of certain rocks. The season's work was concluded by a trip up the valley of the Kúnhár river, through the British district of Khágán, an appendage of Hazára. In spite of it being frequently impossible to leave the road owing to the neighbourhood of unfriendly tribes, results of considerable geological importance have been yielded by the latter trip.

As I hope at no very distant date to publish a general memoir on the geology of Káshmir territory and the neighbouring districts, the observations of the past season will be but briefly noticed here. The rocks of the several districts will be treated of in the order in which they were visited, commencing with—

I.—North-West Káshmír and the middle Kishanganga valley.

Limestones of Trigama.—In the last paper of this series,[1] it was stated that the limestones occurring near the village of Trigama, at the north-western extremity of the valley of Káshmír, were probably in part of triassic age, though they had hitherto been referred exclusively to the carboniferous. A re-examination of these rocks has now shown that they agree exactly in all their characters with the trias, or (?) trias-jura, of other parts of the Káshmír valley, and they have accordingly been referred to that series. These limestones do not cross the watershed of north-western Káshmír. On their northerly and easterly borders they are underlaid by some shaly and slaty beds (often of a greenish hue), mixed with earthy limestones, which are doubtless the representatives of the carboniferous. On the western border of the series the basal beds are in great part concealed by alluvium. No fossils have yet been obtained from these rocks, and accordingly the limits of the carboniferous can only be approximately indicated.

Other outliers of carboniferous and triassic rocks in north-west Káshmír.—In various places in the north-west of the Káshmír valley, and in the district between that and the lower Kishanganga valley, numerous small outliers of limestones and shales are to be met with, whose distribution is sufficiently indicated on the map, and, therefore, does not need further particularising. These rocks overlie, in all cases, the older palæozoics, and contain representatives of both the carboniferous and trias, though the exact discrimination between the two, in the absence of fossils, is a matter of considerable difficulty and uncertainty. The occurrence of these rocks in the tributary valleys of the lower Kishanganga is a matter of some importance, since, from their great resemblance to the limestones of the outer hills with which they are in proximity, and from their identity with the undoubted carboniferous and trias of Káshmír, they afford a strong confirmation of the view already entertained as to the carboniferous and triassic age of the latter limestones, and of the similarly situated band further to the south-east in the outer hills. The absence of fossils from the undoubted carboniferous and trias of north-western Káshmír, and from the corresponding rocks of the lower Kishanganga valley, affords a negative point of connection between these rocks and the unfossiliferous limestones of the outer hills.

Older palæozoics of north-west Káshmír.—The older palæozoics of north-west Káshmír, in their unmetamorphosed state, continue across the Kishanganga in the lower part of that valley; but higher up that valley, between Títwál and Changa, the river crosses their north-western boundary, and above this point their limit, for some miles, lies at some distance to the south of the river, the boundary again crossing the river in the Fúlme (Foolmai) district, and thence sweeping round to the north of the secondary basin of Tilel, described in previous papers. The mineralogical composition of these rocks varies considerably in different districts, trappean rocks occurring more abundantly on the

[1] *Supra*, Vol. XIV, p. 30.

northern flanks of the Káj-nág range, while shales and slates are more abundant in the Kishanganga valley. Here, as has been already noted in previous papers, as in other parts of Káshmir it has not yet been found possible to subdivide these rocks into minor divisions from the evidence of strata of distinct mineralogical composition.

A section in the neighbourhood of the Tútmári pass, of the rocks below the trias, may be instanced as a fair average example of these rocks:—

Blue limestones and shales, the latter frequently carbonaceous . . .	carboniferous.
Dark coloured shales, slates, sandstones, &c.	silurian?
Quartzites, sometimes with gneissic structure, slates, amygdaloids, and conglomerates.	
Porphyritic-gneiss-granite	Primitive?

From this section it will be seen that the amygdaloids occur at a horizon far below the carboniferous, thus differing from the Káshmir sections described in previous papers, where the amygdaloids and other traps immediately underlie the carboniferous. Among the traps of this district there occurs a rock, with a peculiar star-shaped arrangement of crystals, named by the late Dr. Verchere soolimanite.[1] The conglomerate mentioned in the foregoing section is seemingly the same as that occurring in the Pir-Panjál: it here apparently occupies a somewhat low horizon in the series, and probably has a constant position. In Pángi, on the Chináb, Colonel McMahon has lately come to the conclusion[2] that the conglomerate occurring in the slates of that district is probably the equivalent of the so-called Blaini conglomerate of the Simla district, which has been referred to the upper silurian period. Before seeing Colonel McMahon's paper I had come to the same conclusion as to the homology of this conglomerate in Káshmir, for it appeared to me highly improbable that such a widely distributed rock should not belong to the same horizon. I am, however, by no means sure whether this horizon can be certainly fixed as upper silurian, seeing that in Káshmir these rocks seem to always occur a long distance below the fossiliferous carboniferous horizon. It may be, however, as I have often suggested, that in Káshmir a considerable portion of the trap and slate series, usually classed as silurian, is carboniferous. The Blaini limestone of the Simla district, according to Colonel McMahon's identification, should correspond with the part of the Káshmir slates immediately overlying the conglomerate.[3]

Metamorphics of the Káj-nág.—In the foregoing section the lowest rock exposed is a porphyritic gneiss-granite, the same as that already described in

[1] 'J. A. S. B.,' Vol. XXXV, pt. II, p. 120. This rock was named from its occurrence in the hill known as the Takht-i-Sulimán (throne of Solomon) at Srinagar in Káshmir. As the rock is generally found detached in worn boulders, and is of intense hardness, I have been unable to hammer off a specimen for examination. It is easily recognized in the field by its fine-grained green base, with many-pointed radiating stars of small white crystals scattered through it, and is valuable in identifying the Káshmir traps when met with out of the valley. Dr. Verchere describes it as a "passage between a trachyte and a felspathic porphyry."

[2] *Supra*, Vol. XIV, p. 309.

[3] I defer further remarks on this point until I have personally visited the Chamba territories in the neighbourhood of Pángi.

previous papers as occurring on either side of the Jhelam gorge below the Káshmír valley. The mass of this gneiss on the northern side of the Jhelam does not form a continuous core down to the Kishanganga valley, but merely a comparatively small island where the highest peaks of the Káj-nág range are situated. The slates overlie this gneiss, and dip away from it on all sides. Unfortunately no distinct section, exhibiting the junction of the gneiss and slates, was seen; but from its resemblance to the gneiss, classed as primitive in other parts of the Himalaya, I am inclined to think that this Káj-nág gneiss is likewise primitive.

Gneiss south of the Jhelam.—In previous papers of the present series, it has been shown that a core of gneiss forms the back-bone of the Pír-Panjál range. Immediately south of the Jhelam this gneissic core consists of the above-mentioned gneiss-granite, together with some schistose gneiss. This mass of gneiss is, however, not continuous with that of the Pír-Panjál pass, described in a former paper, since the section across the Nílkanta pass exhibits no gneiss at all. The gneiss of the Pír-Panjál and Banihál passes is entirely of a schistose type between these two points: but the occurrence of gneiss pebbles in the conglomerate of the Pír-Panjál indicates the existence of some gneiss of a primitive type. From the difference in the mineralogical composition of the gneiss in the neighbourhood of the Jhelam, and that of the Pír-Panjál pass, I am now inclined to think that the latter is very probably altered palæozoics, while the former, as already stated, is primitive.

Metamorphics of north-west Káshmír.—To the northward of the great mass of slaty rocks, noticed above, as occurring at the north-western end of the Káshmír valley, we come upon another vast series of metamorphic and sub-metamorphic rocks, belonging to more than one geological period, continuous to the north-east with similar rocks in Dárdistán and Baltistán, described in the preceding paper of this series,[1] and to the north-west continuous with the metamorphic rocks of Khágán, noticed in the sequel.

In the Kishanganga valley these rocks occasionally consist of thin bands of a granitic but more usually of a schistose gneiss, varying in its degree of crystallization till it passes into scarcely altered slates; many of the schists are highly micaceous, and frequently garnetiferous. At the village of Changa, and again higher up the river at Doga, there are found overlying these schists, or sometimes folded in among them, certain more or less altered limestones or dolomites, which from their characters seem undoubtedly to correspond to the trias of the Káshmír valley. The occurrence of these limestones indicates pretty clearly that, at all events, some of these gneissic rocks must be the altered representatives of the palæozoics,—a conclusion which we shall find confirmed when we come to treat of the rocks of Khágán. The higher parts of the lofty range separating the Kishanganga from the Khágán valley consist of a granitic and frequently porphyritic gneiss, almost certainly primitive ('central'). Here a considerable difficulty presents itself in regard to the colouring of the map, since in Khágán the primitive and the palæozoic gneisses can be easily separated

[1] *Loc cit.*

and distinguished on the map, while, as noticed in my last paper, no such separation has been found practicable in Baltistán. Hence, in this intermediate country, it is almost impossible to give a true representation, and it must be observed that while in Khágán and the lower Kishanganga valley the gneiss of the two ages is distinguished by different colours, yet in the upper Kishanganga valley, and to the north and east of the same, the one colour on the map (red) must be considered to embrace gneiss of two ages, the easterly termination of the purple area on the map being merely an arbitrary one, and not in the least representing the real distribution of the newer gneiss.

To the north-east of Shardi, on the Kishanganga, the garnetiferous schists are again underlaid by a highly crystalline and sometimes granitic gneiss, pebbles of which are found in the palæozoic conglomerate somewhat higher up the river. Still higher up the river the granitoid gneiss is underlaid by the garnetiferous schists, probably a case of inversion. At the village of Kol.[1] and up the valley leading thence northward, there occurs much of the "augen-gneissth" of Astor, described in my last paper. As at Astor, it is impossible to say whether this gneiss be primitive or altered palæozoic.

Metamorphosed trias.—Up the tributary valley (Brai valley) to the northward of Kol, the "Augen-gneissth" is overlaid by less completely crystalline schists. Near the upper end of the same valley there occur numerous small outliers of the characteristic banded trias limestones and dolomites of the upper Kishanganga valley, more or less altered by metamorphic action. These altered calcareous rocks conformably overlie the gneiss, and are sometimes found capping the highest peaks and ridges, and in other places let down deep into the river gorges, being not unfrequently completely inverted among the gneiss. The distribution of these outliers can only be approximately indicated on the map. No carboniferous horizon can be detected among these triassic outliers, but their presence affords abundant evidence to show that the underlying schists must contain representatives both of the carboniferous and silurian; while, from the presence of pebbles of gneiss in the palæozoic conglomerate, it seems equally clear that a moiety of the metamorphic series must be primitive. The position of these outliers in the Brai stream is such that they lie exactly on the line of strike of the great triassic basin of the upper Kishanganga (Tilel) valley, whence we may conclude that this basin once extended much further to the north-west than at present. In my last paper it was stated that a mass of similar limestones had been noticed by the late Mr. Vigne as occurring in the Indus valley in Chilás, on the strike of the Kishanganga trias: it is probable that this mass of limestone is another triassic outlier among metamorphic rocks. These metamorphic triassic limestones of the Kishanganga basin are precisely similar to those of Baltistán described in my last paper.

Northerly termination of Kishanganga secondary basin.—The secondary basin of the Kishanganga valley and the Zoji-lá has been already described in previous

[1] There is a considerable error in the map (copied from the Indian atlas) at this point, the mouths of the Brai stream, and the stream from Machel, on the opposite side of the Kishanganga, being represented as opposite one another, whereas they are really about 4 miles apart.

Lydekker

GEOLOGICAL SURVEY OF INDIA

Records Vol. XV Pl.

Ideal Section from S.E. of Gaggangir in Sind Valley to the neighbourhood of Drás

Scale 2 Miles = 1 Inch

a = Trias b = Carboniferous c = Silurian

papers, though its northerly termination was not fixed. It has now been found that it extends only a short distance to the north-west of Gurez, the carboniferous rocks sweeping round the trias to become continuous with those of the Kamri pass and Burzil river. The carboniferous is underlaid by the older palæozoic slates, which a short distance to the north-west pass gradually into the great mass of metamorphics of Dárdistán and Baltistán.

Rocks of Sonamarg and the Zoji-lá.—A re-examination of the rocks in the neighbourhood of Sonamarg and the Zoji-lá, at a time when the country was free from snow, has resulted in an entirely different determination of the age and relations of several of these rocks from that previously entertained by myself.[1] It has hitherto been considered that on the southward border of the Sonamarg trias no carboniferous strata existed, the palæozoic amygdaloids adjoining the trias, and a fault existing at the line of junction. The closer examination of the carboniferous of the Káshmír valley undertaken last year has, however, shown that certain carbonaceous and pyritiferous shales, and blue, frequently quartz-veined, limestones, occurring immediately above the amygdaloidal rocks of Sonamarg, must be the representatives of the carboniferous, from their identity in mineralogical structure with the fossiliferous carboniferous of Wardwan and Káshmír. These rocks, which form a very thin band, are succeeded by the trias, as is shown in the accompanying section. The triassic rocks have at first a northerly dip, subsequently becoming southerly, after which, owing to inversion, it again attains its northerly direction; approaching the Zoji-lá, this trias is overlaid by the same carboniferous rocks as occur at Sonamarg. On the same side of the pass the carboniferous rocks are in turn overlaid by slates and greenish trap-like rocks, which must now be considered as the representatives of the older palæozoics. These rocks were originally so classed by Dr. Stoliczka; but observations made by myself in the upper Lidar valley (Panjtárni) led me to the conclusion that they were newer than the trias. In that district the section showed that the slates rested on a synclinal of the trias, whence it was inferred that they were the newer of the two. The conclusion now arrived at as to the relations of the same rocks on the Zoji-lá leads to the inference that in the Panjtárni section the slate rocks must really form an inverted anticlinal below the trias, spreading out above in a fan-shaped manner so as apparently to overlie the latter. To the south-east of the road leading up to the Zoji-lá the strata appear to be in normal sequence, the palæozoic slates dipping to the south-west and south-east and underlying the limestone series. The anticlinal, formerly stated to occur in the trias near Báltal, seems to be merely an inversion.

II.—THE LOWER KISHANGANGA VALLEY AND KHÁGÁN.

Tertiary rocks.—In the lower Kishanganga valley the palæozoic slates of Káshmír extend to within a couple of miles of the village of Pala, sweeping round in a horse-shoe form on either side to Nága station on the south, and Makra station on the north. Within this horse-shoe or bay of older rocks there occurs a large

[1] The Sonamarg district is shown in the map accompanying my last paper.

extent of the red tertiary rocks of the Murree group.[1] These and other tertiary rocks occupy the rest of the Kishanganga valley, and are continuous with those of the Jhelam valley, while to the north they extend into Khágán. The junction between the tertiaries and the palæozoics seems to be an original one, the rocks of both series presenting a parallelism of stratification, with a general highly inclined outward dip, though there is very frequently slight inversion: further to the west this inversion becomes the rule. The red Murree rocks continue to within a short distance of Musafirabad (Mozafirabad), where they are underlaid by limestones, crowded with nummulites.[2] These nummulitic limestones form a tongue, stretching in from the north-west and cutting off almost entirely the Kishanganga and Khágán Murree rocks from those of the Jhelam valley, though there is a narrow communication near Chenasi station. The 'tongue' of nummulitics probably forms an anticlinal axis, inverted towards the south. It would seem from the relations of the Murree rocks to the palæozoics that the nummulitics were 'overlapped' by the former rocks, and that they never underlay the whole tertiary area. The Musafirabad nummulitics unite with the band bordering the right bank of the Jhelam below the Musafirabad bend: to the north these limestones continue to a point a little beyond Bála-kot, being overlaid to the north and east by Murree beds. In the Khágán valley the tertiaries form another bay, rather smaller than the one in the Kishanganga valley. The lower part of this bay is formed by Murree beds, and the higher by nummulitic limestones; the bordering rocks are in all cases palæozoics.

Relations of tertiaries to older rocks.—At the junction of the nummulitics with the palæozoics, on the Kúnhár river below Khágán, the strata are nearly vertical, with a slight south-westerly dip, the nummulitics overlying the palæozoics. There appears to be strict parallelism between the strata of the two rock series, as far as can be observed in the limited portion visible in the section. A similar relation of the palæozoics to the tertiaries has been previously noticed in Ladák.[3]

General conclusions on the tertiaries.—The occurrence of the bay of tertiaries

[1] It may not be out of place to mention that, from the middle rocks of the Murree group, near Chakoti, in the Upper Jhelam valley, I obtained last autumn a fragment of the frond of a palm, belonging to a species which Dr. Feistmantel has described below as being very closely allied to, if not identical with, *Sabal major*, of the middle and lower miocene of Europe. The occurrence of this miocene palm in a horizon far below that of the mammaliferous siwaliks is of some importance, as it goes some way in confirming the conclusions previously arrived at by Mr. W. T. Blanford and others, as to the pliocene age of the latter. The presence of nummulites marks the eocene age of the Subáthu group. The present fossil indicates the miocene age of the Murree group (the fossil was found about the middle of this series); and hence, on this evidence alone, the Siwaliks should be pliocene.

[2] These Musafirabad limestones have been the source of considerable discussion and difficulty. In the first paper of this series (*Supra* Vol. IX, p. 155, *et seq.*) they were classed as nummulitics (Subáthu) but were confounded with the palæozoics to the northward. In a subsequent paper (Vol. XII, p. 16), owing to this mistake and the non discovery of nummulites in the limestone at Musafirabad, I came to the conclusion that these rocks must be the equivalent of the Uri limestones higher up the Jhelam valley, and hence of early mesozoic or late palæozoic age. The observations of the past season have finally set the question at rest.

[3] *Supra*, Vol. XIII, p. 29.

running up the valley of the Kúnhár and Kishanganga rivers is a fact of much geological interest. The presence of this bay, taken together with the circumstance that the inner tertiary boundary is immediately outside a snowy range, the nature of that boundary, and the non-occurrence of any tertiary rocks beyond it, seem to point to the conclusion that that boundary is approximately an original one, though, of course, the limits of the strata have been somewhat curtailed by denudation.[1] Hence we may probably infer that the Káj-nág and Pír-Panjál range marks an old shore line, while the Jhelam flowed into the sea or estuary at Uri,[2] and the Kúnhár and Kishanganga rivers, by distinct mouths into a gulf northward of Muzafirabad. From these observations it will follow that the present drainage lines of the country must have existed in early tertiary times.

The lower Murree beds are certainly of marine origin, as they locally contain nummulites; while, from the occasional occurrence of fresh-water shells in the higher beds of the series, we may infer that the latter are of fresh-water or brackish origin. Hence it seems probable that the nummulitic sea gradually receded, and was replaced by estuaries and lagoons. We may further infer that Himalayan land existed in eocene times, forming a shore of the eocene sea, and affording material for the immense series of tertiary deposits. Considering that we have fair evidence that the Pír-Panjál and Káj-nág range formed an old shore line, it seems remarkable that no pebble beds are found in the lower tertiaries. This may, perhaps, be explained as follows:—Seeing that in most places where the junction between the palæozoics and tertiaries has been observed, (as in Khágán and on the Jhelam at Uri,) there is a strict parallelism between the two series of strata, frequently (as at Uri) with inversion, we must suppose that the palæozoics forming the old shore line had originally a low and gradual dip towards the sea; the tertiaries would then be thrown down upon these rocks with the same general inclination which, in a limited area, would appear parallel. Further, since the older rocks dipped towards the sea, they would be but slightly affected by denudation, and since the sea may have been a currentless gulf, it is not so difficult to imagine the absence of a pebble beach. Finally, a steady upraising of the whole area by a lateral thrust would very easily crush the tertiaries against the palæozoics and invert the latter upon them. It may be concluded from this, that here, as suggested by Mr. Medlicott ("Manual," pp. 569,960), a great upheaval and denudation of the older rocks took place in pre-tertiary times, while the great epoch of contortion and crushing took place subsequently.

Extinction of gneissic axis of the Pír-Panjál at the Kishanganga valley.—In the "Manual of the Geology of India," it has been concluded[3] that the valley of the Kishanganga at Muzafirabad, and of the Jhelam below its great bend at that place, formed the boundary of the Himalayan area proper. This conclusion is strikingly confirmed by the bay of tertiary rocks occurring in the lower Kishanganga valley, and by the gradual but complete extinction, some distance to the south-

[1] The opinion at first expressed by myself (*Supra*, Vol. IX, p. 155), that this boundary was a faulted one, will not hold.

[2] See map accompanying paper last quoted.

[3] pp. 478, 518.

east of this valley, of the gneissic axis of the Pír-Panjál range,—an axis which can be traced up to this point continuously from the Dhauladhár range, with but slight interruption, and, as we approach the valley of the Kishanganga, becomes gradually less and less marked until its final disappearance beneath a mass of silurian and carboniferous rocks in that valley. The gneiss to the westward of the Kishanganga belongs to an entirely different mountain system, namely that of the Mustág and Chilás ranges of Baltistán and Ladák, described in previous papers of this series.

Older rocks of Khágán.—Reverting to the rocks of Khágán, we may continue our survey by commencing at the upper end of the valley, where we find the rocks of the valleys and bordering ranges to consist mainly of a compact gneiss-granite, frequently porphyritic, with large twin crystals of orthoclase, but more generally fine-grained. This gneiss-granite is undoubtedly identical with the similar rocks described in my last paper as occurring so frequently in Baltistán, and apparently the representative of the central gneiss of Dr. Stoliczka. It is, however, quite probable that among this gneiss there are beds of the newer gneiss.

In several places on the south side of the upper Khágán valley, this primitive gneiss, frequently lacking all signs of stratification, is distinctly seen to be overlaid by a newer and schistose gneiss, with considerable indications of unconformity. This newer schistose gneiss, and other schists, are frequently highly garnetiferous and micaceous. As we descend the valley, the newer schists gradually become less and less crystalline, till near the village of Khágán itself they become almost unaltered slates and shales; while below that place they pass into greenish sandy and slaty rocks, undoubtedly the same as many of the older palæozoics of Káshmír. In various parts of upper Khágán these semi-metamorphic rocks are overlaid by carbonaceous and pyritous shales, which have undergone a partial metamorphism, and these again by a hard white or buff metamorphic limestone or marble. The close resemblance of these rocks, whose distribution is approximately indicated on the map, to the metamorphosed trias of the Kishanganga valley, and also to the unaltered carboniferous and trias of the Káshmír valley, indicates a strong presumption that they are the same; it is further probable that the representatives of the Hazára 'Tanol' group of Mr. Wynne are represented among these rocks.

Frequently, owing to the extent to which the metamorphic action has been carried, the presumed carboniferous zone cannot be detected. The presence of these rocks, if rightly assigned, confirms the conclusion that the newer Khágán gneiss, which is the same as that of the lower Kishanganga, is the altered representative of the palæozoics.

Unknown rocks.—In upper Khágán, at the village of Soch, there occur certain greenish sandstones, mingled with some slightly altered blue limestones, and some shales, resting on the gneiss. These rocks are left uncoloured on the map, as I cannot determine their age: they are not unlike some of the nummulitics, but I could find no trace of nummulites in the limestones.

Rocks of Northern Hazára.—In conclusion, a few remarks may be added, as to the correlation of the rocks of northern Hazára, comprehending the lower portion of the course of the Kúnhár river, and the adjacent country to the west and south with those of Khágán. The latest report on the geology of Hazára is by Mr. Wynne, and will be found in the 12th volume of the "Records,"[1] accompanied by a map, which includes part of the area exhibited in the map accompanying the present notice. In the two maps some slight differences will be noticed, occasioned by the different estimates taken by Mr. Wynne and myself of the distinctions between slates and schists. A short notice of the section between Murree and Abbottabad, in Hazára, is given by Mr. Wynne in the same volume;[2] and the geology of the Sirban mountain in lower Hazára is treated of by the same gentleman in the 9th volume of the "Memoirs."

In northern Hazára Mr. Wynne distinguishes the following divisions of the infra-jurassic rocks, *viz.*:—

4. Trias { upper / lower.
3. { Infra-trias / and Tanol series, passing to the north into gneissic rocks.
2. Attock slates.
1. Hazára gneiss.

The trias Mr. Wynne identifies with that of Káshmír, and there can be no doubt that this is correct.

The age of the Tanol rocks is not determined, but it is evident that this must lie between some part of the palæozoic and the trias.

The Attock slates are concluded to be palæozoic, with a possibility of being silurian. Mr. Wynne doubts whether these rocks are the same as the silurian of Káshmír, mainly on account of their non-association with gneiss.

The Hazára gneiss is identified with that of the Káj-nág (Pír-Panjál) range, but is said to be differently placed.

In Mr. Wynne's map[3] there appears a large series of schistose rocks, lying to the north of Abbotabad. These rocks do not appear in the table given on page 128 of Mr. Wynne's notice, unless they be included in the Tanol series. They are undoubtedly the same as the newer gneiss of Khágán, which has been shown to contain representatives of the palæozoics.

My own observations tend to point to the intimate relationship of these schists with the Attock slates; the rocks on the lower Kúnhár river, mapped as such by Mr. Wynne,[4] appearing to pass imperceptibly into the newer gneiss and other schists, of Khágán to the north, and of Hazára to the south-west. I am thus led to conclude that the newer gneiss series (or schists of Mr. Wynne), is, at all events in great part, the metamorphosed representative of the Attock slates. Both these rock series would, therefore, seem to correspond to the slate series of Káshmír, which has been mainly classed as silurian, though there is a possibility of its upper part being carboniferous.

Since the publication of Mr. Wynne's notice of northern Hazara, Dr. Waagen has suggested[5] that the Attock slates may be of carboniferous age, his suggestion

[1] p. 114, *et seq.*
[2] p. 208, *et seq.*
[3] *Supra*, Vol. XII, p. 122.
[4] *Ibid.*, p. 130 (Mr. Wynne terms the Kúnhár the Nainsúk river).
[5] *Supra*, Vol. XII, p. 184.

being based on the evidence of a carboniferous brachiopod, embedded in dark shale, said to have been obtained from the Punjab. The evidence connecting this fossil with the Attock slates is, however, only circumstantial.

Seeing that, according to Mr. Wynne, the Tanol group overlies the Attock slates with marked unconformity, it seems difficult to accept the view of the carboniferous age of the former, since there would thus seem to be no place for the Tanols. Perhaps a way out of the dilemma might be found by considering that merely the topmost Attock slates are of carboniferous age. Even then however, we have the Tanols vastly thicker than the undoubted carboniferous of Káshmir, to say nothing of the unconformity between the Tanols and the trias.

The Hazára gneiss of Mr Wynne is undoubtedly the same as that of upper Khágán, where we have seen it underlying the newer schists, and doubtless corresponds to the 'central gneiss' of Dr. Stoliczka. Its apparent super-position on the newer schists in Hazara must be due either to inversion on a very large scale, or to a fault.

In confirmation of the view of the correspondence of the Attock slates with the slate series of Káshmir, I may add that I have this season identified, as far as this can be done from exact structural similarity, the slates occurring on the upper road from Abbottabad to Murree at Kálabágh, described by Mr. Wynne as Attock slates,[1] and those occurring in the gorge leading from Láma-Yuru to Kalsi on the Indus in Ladák,[2] considered both by Dr. Stoliczka and myself as being probably of silurian age. Similar rocks occur at Drás, on the Káshmír and Ladák road, and have been identified with the great mass of the slate series of Káshmir. The proximity of the same Káshmir slates in the Kishanganga valley to the Attock slates of the lower Kúnhár valley seems of itself sufficient proof of the identity of these rocks.

On some Gondwána Labyrinthodonts, *by* R. Lydekker, B.A., F.Z.S., *Geological Survey of India.*

(With a Plate).

Introductory.—Since my last notice of Gondwána vertebrates,[3] Professor Huxley has returned to the Indian Museum certain remains of labyrinthodonts from the Panchet and Maleri groups of the Gondwána rock series, some of which are of sufficient interest to merit a short notice here, as they illustrate more fully than previous specimens the structure and distribution of certain forms of these interesting salamandroid animals. In the plate accompanying this notice some of the best preserved of these remains have been figured, together with (fig. 1) the small lower jaw of a Panchet labyrinthodont collected by myself last year, and referred to in the above-quoted notice. I now proceed to notice the various specimens *seriatim*.

Mandible of Pachygonia incurvata *from the Panchet group.*—In his description of the "Vertebrate Fossils from the Panchet Rocks,[4]" Professor Huxley

[1] *Supra*, Vol. XII, p. 209.
[2] *Ibid*, p. 48.
[3] *Supra*, Vol. XIV, p. 178.
[4] "Pal. Ind." Ser. IV., Vol. I, pt. 1, p. 6.

described and figured the hinder moiety of the left ramus of a labyrinthodont mandible under the new name of *Pachygonia incurvata*. This lower jaw is characterised by its roughly sculptured outer surface, and by its carrying a row of minute teeth, transversely elongated at their bases, but becoming sub-cylindrical higher up. The part of the dentary element remaining in the specimen is nearly straight, with a slight indication of the symphysial incurving.

At a subsequent date I described[1] the symphysial portion of another labyrinthodont mandible from the same formation, which was referred to the same species. This specimen showed a series of small teeth, placed along the free edge of the ramus, like those in Professor Huxley's specimen, and also a single and larger isolated tooth placed internally to the marginal series in juxtaposition to the symphysis.

In figure 2 of the plate accompanying this notice is represented the dentary portion of the right ramus of a labyrinthodont mandible from the Panchet group of rocks, being one of the specimens returned by Professor Huxley The anterior portion of this specimen is precisely the same as the fragment of the symphysis described by myself. The hinder part of this specimen, as far forward as the point where the teeth become separated by a distinct interval, corresponds with the anterior part of Professor Huxley's specimen; the new jaw is, however, rather deeper than the latter, and must have belonged to a somewhat larger individual. The new specimen makes us, therefore, acquainted with the whole of the mandible of *Pachygonia*. It will be noticed that the hinder teeth are closely approximated, transversely elongated at their bases, sub-cylindrical higher up, and bending in at their extremities. In advance of these approximated teeth are four rather larger teeth, separated by intervals about equalling their own shorter diameters. In advance of these, we again find another series of smaller and closely approximated teeth, continuing up to the symphysis, as in many other labyrinthodonts. There is one large isolated tooth placed close to the symphysis, and internally to the marginal series.

In describing his specimen, Professor Huxley remarked that "inside the dentary piece there seems to be a distinct splenial element......It exhibits minute, round, crater-like elevations, as if (as is the case in some Amphibia and Ganoid fishes) it had given attachment to teeth." The absolute correctness of this suggestion is illustrated by the new specimen, for this shows on its inner surface a small remnant of a splenial element, bearing two minute teeth; this probably continued along a considerable portion of the hinder part of the dentary piece. The outer wall of the mandible is nearly vertical, and of great relative depth at the symphysis. The general form of the complete mandible was probably very similar to that of the European *Labyrinthodon pachygnathus*.

PACHYGONIA *from the Kota-Maleri group.*—In figures 3 and 4 of the accompanying plate are represented two fragments of labyrinthodont jaws from the Maleri section of the Kota-Maleri group. They were collected by the late Mr. Hislop in Chutia Nagpúr, and were sent to Professor Huxley, who never described them: they are coated with the red clay characteristic of the Maleri

[1] "Pal. Ind." Ser. IV., Vol. I, pt. 2, p. 18, pl. III, figs. 12, 13.

fossils. The fragment represented in figure 3 is a portion of the dentary element of a mandibular ramus, posterior to the symphysis; while that represented in figure 4 is a portion of a left ramus, immediately contiguous to the symphysis. These fragments so closely resemble the above-described jaws of *Pachygonia incurvata*, that it appears to me that they may be safely referred to the same genus, and not improbably to the same species.

The identification of a Panchet fossil in the much lower Maleri horizon is a matter of some interest, as hitherto the fossils from these two horizons have been entirely distinct. The present determination makes a closer link between these two series of the great Gondwána system.

GONIOGLYPTUS HUXLEYI (*nobis*) *from the Panchet group.*—Another specimen from the Panchet rocks, represented in figures 5 and 8 of the accompanying plate, consists of the hinder portion of the left ramus of the mandible of a comparatively large-sized labyrinthodont. Figure 5 gives a view of the articular cavity, and figure 8 of the outer surface of this specimen. It will be remembered that in the above-quoted memoir[1] Professor Huxley described and figured a slender labyrinthodont mandible, which he provisionally referred to *Gonioglyptus longirostris*, a species named from the evidence of a fragmentary skull from the Panchet rocks. The relatively common occurrence of fragments of both these skulls and mandibles in those rocks renders it almost certain that this provisional determination is correct, and it will henceforth be assumed to be so.

The fragmentary ramus figured here comprehends only a portion of the articular and angular elements, the supra-angular having been nearly all worn away, the cavity for articulation with the quadrate and the superior part of the articular and angular elements being the only perfect portions. This jaw belonged to an animal nearly three times the dimensions of the one to which belonged the jaw figured by Professor Huxley: it would, however, be doubtful whether size alone would afford grounds of specific distinction, were it not supplemented by certain differences in form. The general form of the larger mandible agrees so nearly with that of *Gonioglyptus longirostris*, that there is every probability of the two having belonged to the same genus. The following points of difference may, however, be indicated:—In *G. longirostris* the sculpturing on the internal surface extends down to the sharp interior border of the jaw, throughout its length. In the larger jaw, on the other hand, the sculpture occupies only the upper two-thirds of the hinder portion of the outer surface, there being a wide and deep groove on the portion unoccupied by the sculpture. The two diverging grooves, so conspicuous on the outer side of the mandible of *G. longirostris*, immediately below the articular cavity, are only very faintly indicated in the larger jaw. There is, further, a considerable difference in the sculpture of the two specimens, which, though easy to recognise, is difficult to describe.

The foregoing differences appear to me to forbid our referring the two mandibles to the same species, and I therefore propose to form a new species for the larger jaw, which may be named *Gonioglyptus huxleyi*. Judging from the

[1] p. 5, pl. VI, fig. 2.

size of the fragment of the mandible, this animal must have attained a length of at least 5 or 6 feet.

Labyrinthodont Symphysis from the Panchet group.—In figure 6 of the accompanying plate, there is represented the inferior view of the right half of the symphysis of the mandible of a labyrinthodont from the Panchet rocks. The figured under-surface shows a portion of the bone marked with sculpture like that of *Gonioglyptus*, and internally to this an exposed surface which would seem to have articulated with a produced splenial element. The superior surface (not figured) has been somewhat rolled, and only shows sections of the teeth. These comprised a marginal series, and one larger solitary tooth, placed more internally, near the symphysis. The superior surface is nearly flat, while the inferior gradually slopes upwards from the hinder border of the symphysis to the anterior border, which consequently forms a sharp edge.

The form of the symphysis shows that this jaw cannot belong to *Pachygonia* in which the anterior border of the symphysis forms a vertical wall in place of a sharp edge. It may belong to one of the species of *Gonioglyptus*, but this cannot be certainly determined.

Mandible of GLYPTOGNATHUS FRAGILIS (*nobis*) *from the Panchet group.*—In my note on Gondwána vertebrates in the last volume of this publication, already quoted, a mandible of a labyrinthodont from the Panchet rocks was described though not named, and shown to be different from the mandible either of *Gonioglyptus* or *Pachygonia*. This specimen has now been figured in the accompanying plate (fig. 1), and it may be well to recapitulate the main points of the description already given. The fragment comprises the greater portion of the right ramus of the mandible, showing the articular cavity, and the greater part of the dentary element. The bases of six anchylosed teeth are shown, decreasing in size from before backwards. The teeth are subelliptical in cross-section, the transverse diameter being the longer. The portion of the jaw remaining is quite straight, very slender, rounded interiorly, and sculptured externally.

The jaw of *Gonioglyptus longirostris*, besides being larger than the present specimen, is distinguished by presenting a trenchant edge, free from teeth, for some distance in advance of the articular cavity; while the jaw of *G. huxleyi* is at once distinguished by its enormously larger dimensions. The jaw of *Pachygonia incurvata* makes no approach to the present specimen.

There is, therefore, no doubt but that this jaw does not belong to any of the named Panchet labyrinthodonts; and as I am unable to identify it with any form from other parts of the globe, and as it is highly inconvenient to have to refer to species without any generic or specific name, I propose to provisionally designate the species to which the jaw belonged as *Glyptognathus* (γλύφω, γνάθος) *fragilis*. Though the specimen is not quite perfect posteriorly, it seems probable that it had no 'supra (post) articular' process, whence it would belong to Professor Miall's group of Brachyopinæ, *Gonioglyptus*, and *Pachygonia*, belonging to the group Euglypta, in which that process is present.[1]

[1] See Miall. "Report on the structure and classification of the Labyrinthodonts." Brit. Assoc. Rep., 1874.

Labyrinthodont vertebra from Maleri.—Among the specimens collected by the late Mr. Hislop in the rocks of the Maleri group, and sent to Professor Huxley, are certain amphicœlous vertebræ of considerable size, which almost certainly belonged to some form of labyrinthodont. One of the more perfect of these bones is represented in figure 7 of the accompanying plate. It is impossible to determine the genus of animal to which these bones belonged, and they are mentioned here merely to indicate the existence of a large labyrinthodont among the Maleri fauna.

It has been suggested to me whether the large dermal scutes found at Maleri and elsewhere might not have belonged to the batrachian rather than to the crocodilian (*Parasuchus*) to which they have hitherto been referred. In regard to this question, it may be observed that dermal scutes and crocodilian vertebræ have been found in association at a place (Rewah) where no batrachian remains have been discovered; also that at Maleri scutes and crocodilian vertebræ are very common, while only five batrachian vertebræ are known; and, finally, that the generally quadrangular form and bevelled edges of the scutes indicate crocodilian rather than batrachian owners. It is, however, quite possible that some of these scutes may have belonged to the latter.

DESCRIPTION OF PLATE.

Fig. 1. GLYPTOGNATHUS FRAGILIS, (Lyd.). Hinder portion of right ramus of the mandible. Panchet group.

Fig. 2. PACHYGONIA INCURVATA (Hux.). Anterior portion of right ramus of the mandible; left ramus restored. Panchet group.

Figs 3 & 4. PACHYGONIA (?) INCURVATA (Hux.). Portions of the mandible. Maleri beds.

Fig. 5. GONIOGLYPTUS HUXLEYI (Lyd.). Upper view of articular cavity of left ramus of the mandible. Panchet group.

Fig. 6. GONIOGLYPTUS ? sp. Superior view of right half of the symphysis of the mandible. Panchet group.

Fig 7. Labyrinthodont vertebra. Maleri group.

Fig. 8. GONIOGLYPTUS HUXLEYI, (Lyd.). Lateral view of hinder portion of left ramus of the mandible. From the same specimen as that represented in figure 5.

Note on some Siwalik *and* Jamna Mammals *by* R. LYDEKKER, B.A, F.Z.S., *Geological Survey of India.*

HYÆNA SIVALENSIS *(Falc. and Caut.)*

In a recent number of the 'Records'[1] Mr. Bose has re-opened the question as to the existence of one or two species of Siwalik hyænas. In this notice the correctness of my own measurements of the specimens in the Indian Museum having been called in question, I am compelled, much as controversies are to be deprecated, to vindicate my own statements.

[1] *Supra*, Vol XIV, p 256

It would appear that from an unfortunate grammatical inaccuracy of mine, Mr. Bose took another skull for the one in which the small upper molar was stated to exist, and hence concluded my measurements were wrong.[1] In order that the question may be settled, as far as this point goes, and also to remove any personal element from the matter, Mr. J. Wood-Mason, Deputy Superintendent of the Indian Museum, has been kind enough to measure the transverse diameter of the tubercular molar in all the three skulls of Siwalik hyænas, in the Indian Museum.[2] In the following table these measurements are given, together with Mr. Bose's measurements of the corresponding teeth in the two British Museum specimens. In the second column of the table the presence or absence of the first upper premolar is indicated, respectively, by a cross or a cypher:—

	Transverse diameter of tubercular.	Presence or absence of 1 p.m.
a. Indian Museum skull D. 44	0·62	+
b. " " " D. 47	0·59[3]	0
c. British " type of *H. sivalensis*	0·55	+
d. Indian " skull D. 45	0·45	0
e. British " type of *H. felina*	0·28	0

A fragment of the maxilla of another Siwalik hyæna in the Indian Museum (D. 101) has the tubercular molar of the same transverse diameter as in the skull *d*; its shorter diameter is, however, 0·19, in place of 0·23.

In spite of my grammatical blunder, it is rather difficult to understand how Mr. Bose, with the three skulls before him, could have overlooked the above-mentioned differences in the dimensions of the tubercular molars, and committed himself to the statement that "all the three skulls in the collection of the Indian Museum agree in respect of the size of the upper tubercular."

Taking into consideration the graduated scale of the variations in the size of that tooth as indicated in the table, it appears to me that, from this point of view, there are not, as I stated before, sufficient grounds for making more than one species. It will be noted that the difference in size of the tooth in question in the skulls *a* and *d* on the one hand, and *d* and *e* on the other, is the same.

If any division were made of the skulls, including the maxilla, it appears to me that it would be necessary to make six species.

The table further illustrates the extreme irregularity in the development of the first premolar, which, in his original paper, Mr. Bose considered to be an important character of his *H. felina*.[4] The development or non-development of this tooth is seen to bear no relation to the size of the tubercular.

Although Mr. Bose in his last notice seems to rely on the small size of the tubercular as the distinctive character of his species, still he mentions that his

[1] The skull mentioned by Mr. Bose is No. D. 47, while the one I referred to is D. 45.

[2] Mr. Wood-Mason's measurement of the tubercular in D. 45 is somewhat larger than mine.

[3] Mr. Bose's measurement is 0·6.

[4] Mr. Bose ('Quar. Jour. Geol. Society,' Vol. XXXVI, p. 131) remarks on the constancy of this tooth in all known species of *Hyæna*, both living and fossil, except his *H. felina*. A cast of a skull of *H. eximea* from Pikermi, exhibited in the British Museum, shows the absence of this tooth.

type skull of *H. felina* is distinguished by its greater shortness and breadth from his *H. sivalensis*. It is, indeed, perfectly true that there is a very considerable difference between the form of the skulls *a* and *c*, the former being elongated and the latter wide. But then the skull *b* is intermediate in these respects, approaching, however, in its wide palate, nearer to *c* than to *a*.

It is not easy to see the force of the support Mr. Bose seems to derive from the confusion made by the Editor of the "Palæontological Memoirs" over the application of the name *Felis cristata*, as was pointed out by Mr. Bose himself in his original paper.[1]

Finally, as was mentioned in my previous notice, I think from the materials available to him, Mr. Bose, following the lead of Dr. Falconer,[2] was probably right in making two species of Siwalik hyænas. The fuller materials available in India, however, seem to me to point to the conclusion that not more than one species can at present be determined.

TRAGULUS SIVALENSIS, nobis., n. sp.

An upper molar tooth of a small ruminant, from Mr. Theobald's collection from the Siwaliks of the Punjab, is indistinguishable from the corresponding tooth of the living *Tragulus indicus*, and doubtless belonged to an animal of the same genus. Since it is impossible to distinguish the different living species from the characters of the teeth alone, it seems best to indicate the fossil by a distinct provisional name, which I propose should be *sivalensis*.

EVOLUTION OF THE GIRAFFES.

A study of the limb-bones and cervical vertebræ of fossil Siwalik giraffe-like and sivatheroid animals in the collection of the Indian Museum, has shown that the Siwalik giraffe was very like the existing species in the proportions of its limb-bones. Nearly allied to this giraffe was another long-limbed ruminant, the leg-bones of which were, however, considerably shorter than those of the giraffe: this ruminant is possibly the same as *Vishnutherium*. Next in the series we have *Hydaspitherium*, whose limb-bones were considerably shorter and stouter than those of the last form, but longer and slighter than those of *Sivatherium*. Finally, those of the latter genus have the proportions ordinarily prevailing among the ruminants.

It is not pretended that the above is the direct line of the evolution of the giraffes, but it may be taken as a true indication whence these remarkable ruminants were evolved. The specimens examined indicate that the families Camelopardalidæ and Sivatheridæ should be amalgamated.

The details on which these conclusions are founded, will be published hereafter in the "Palæontologia Indica."

[1] pp 129, 130.

[2] Dr. Falconer, in a letter to the late M. de Blainville, dated 4th October 1847, referred to the probability of there being two species, both of Siwalik hyænas and tigers. (See "Pal. Mem.," Vol. I, "Corrigenda and Addenda.")

HELLADOTHERIUM.

In figure 1 of plate A of the unpublished plates of the "Fauna Antiqua Sivalensis,"[1] the skull of a large hornless ruminant from the Siwaliks is represented under the name of the female of *Sivatherium giganteum*.

In describing the skull of *Helladotherium duvernoyi* from Attica, M. Gaudry writes in reference to a cast of the above skull.[2] "le crâne a la même taille que celui de l'*Helladotherium*, et la ressemblance générale est frappante; à la vérité, ses prémolaires sont un peu plus grandes comparativement aux arrière-molaires, sa face palatine s'avance moins, ses condyles occipitaux ne sont pas aussi forts, la face postérieure n'a pas de chaque côte de la crête occipitale un enfoncement profond. Mais, si on tient compte des variations qu'un animal a pu subir en passant de l'Europe dans l'Inde, on sera sans doute disposé à rapporter le crâne dont je parle à l'espèce de Grèce. M. Falconer, qui a examiné nos fossiles, penche vers cette opinion."

I have not hitherto admitted *Helladotherium* into the Siwalik fauna, but a careful comparison of the cast of the above-mentioned skull with M. Gaudry's figure of the skull of *Helladotherium* leaves no doubt in my mind that the two skulls belong, at all events, to the same genus. The question, of course, suggests itself as to whether *Helladotherium* can be the female of *Sivatherium*, but this is negatived by the greater length of limb of the former animal.

The original assignation of the skull in question to the female of *Sivatherium* seems only to have been a guess, founded upon the similarity of the teeth, as the skull really presents no marked resemblance to that of the latter genus. Judging from the analogy of the giraffe,—the nearest living ally of these fossil animals,—it would be more probable that when horns were developed at all, they were present in both sexes.

It is somewhat remarkable that the late Dr. Murie, in his memoir of *Sivatherium*,[3] makes no mention of M. Gaudry's reference of the so-called female of that genus to *Helladotherium*.

I think the Indian species must be provisionally known as *H. duvernoyi*, as its skull seems to present no sufficient points of distinction from the Attic form.

HIPPOPOTAMUS IRAVATICUS (Falc. and Caut.)

In the "Fauna Antiqua Sivalensis," according to the lettering of the plates, and their posthumous description, all the remains of hippopotamus from the sub-Himalayan Siwaliks are referred to *H. sivalensis*. Two fragments of the symphysis of a six-toothed mandible are, however, represented in figures 10 and 11 of plate LVII of that work under the name of *H. iravaticus*, and came from Ava. No other specimens are figured under the same name;[4] and as no description is given, the grounds on which Dr. Falconer specifically distinguished these speci-

[1] Autotype copies of these plates can be obtained at the British Museum.

[2] "Animaux Fossiles et Géologie de l'Attique," p. 260.

[3] "Geological Magazine", Vol. viii, p. 438. M. Gaudry's work was published in 1862, and Dr. Murie's memoir in 1871.

[4] Except a radius in plate lxxxiii, fig. 12.

mens are unknown. The Ava specimens seem, however, to be of smaller size than the others.

In the Indian Museum there is the lower end of the left radius of a very small hippopotamus from Ava, described by Dr. Falconer in his catalogue of the Siwalik collection of the Asiatic Society of Bengal (No. A. 303)[1] as belonging to his *H. iravaticus*, stated to correspond very closely with the specimen represented in plate LXV, figure 18, of the "Fauna Antiqua Sivalensis" (as *H. sivalensis*). In the same catalogue another bone (No. A. 307) is described as belonging to *H. iravaticus* in the following words: "Lower end of left femur, showing the articulating condyles and a part of the shaft, both much weathered and the surface abraded, so as to render the character[s] indistinct. The bone is proportionately of much smaller size than *Hippopotamus sivalensis*, and would thus agree with the dimensions of the radius, No. 303, and with specimens assigned to *Hippopotamus iravaticus* in the "Fauna Antiq. Sival."[2]

This is all that is known regarding the species, from which we gather that its remains were obtained from Ava, that it was 'hexaprotodont,' and that it was of much smaller dimensions than *H. sivalensis*, which equalled in this respect the large African species.

During a recent visit to England, Mr. W. Davies, of the British Museum, showed me several limb-bones of a very small but adult hippopotamus from the Siwaliks, which we considered must probably belong to *H. iravaticus*.

In recently cataloguing the remains of Siwalik hippopotamus in the Indian Museum, a left ramus of the mandible (No. B 395) has from its small dimensions appeared to me very probably to belong to Falconer's *H. iravaticus*. The following are the dimensions of this specimen compared with those of the jaw of *H. sivalensis*.

	H. iravaticus.	H. sivalensis.
Depth of jaw at 2nd true molar	4·2	4·4
Length " five last teeth	7·7	8·5
" " first true molar	1·21	1·5
Width " " " "	0·95	1·3
Length " 2nd " "	1·68	1·9
Width " " " "	1·22	1·55
Length " 3rd " "	2·2	2·82
Width " " " "	1·3	1·6

These dimensions show that while the depths of the two jaws are practically the same, there is a great difference in the size of the teeth: the hinder border of the symphysis is also placed farther forward in the smaller jaw. The pattern of the grinding surfaces of the molars in all species of hippopotamus is so similar that no grounds of distinction can be drawn from their teeth.

Although distinctions merely on the ground of differences of size require to be received with extreme caution, yet the proportions observed in the jaw before

[1] See "Pal. Mem.," Vol. I, p. 142.

[2] The instance of the small radius figured in plate LXV, fig. 18, leaves it doubtful whether this statement applies to the mandibles figured as *H. iravaticus*, or to limb-bones figured as *H. sivalensis*.

us, as compared with those of the jaw of *H. sivalensis*, seem to point to the correctness of Dr. Falconer's conclusions as to the existence of a second smaller species of Siwalik hippopotamus.

MAMMALIAN FOSSILS FROM THE JAMNA ALLUVIUM.

Mr. J Cockburn, of the Opium department, has recently presented to the Indian Museum a small series of mammalian bones, collected by him in the older pleistocene alluvium of the Jamna and its tributaries, in the Bánda district. These remains are in most cases thoroughly mineralised, like the Narbada fossils. They are, however, with a few exceptions, in a very fragmentary condition, so that their specific determination is impossible They may be referred to the following seven genera, *viz.*, *Elephas*, *Bos or Bubalus*, *Portax*, *Antilope*, *Rhinoceros*, *Equus* and *Felis*.

The antelope seems to be identical with the black-buck, *A. cervicapra*. The rhinoceros cannot be specifically determined, but as it was furnished with lower incisors, it cannot have been *R. deccanensis* of the Krishna valley pleistocene; it may have been *R. indicus* The species of *Felis*, a genus, like the last, hitherto unknown from these deposits, is represented by a nearly perfect specimen of the right scapho-lunar bone, which is of slightly larger size than the corresponding bone of a full-sized Bengal tiger Beyond this slight difference in size, the two bones do not present any appreciable points of distinction, and may have very probably belonged to the same species. It would, however, be rash on this scanty evidence to say that the pleistocene tiger was certainly the same as the living species.

With the remains of a small, specifically indeterminable, horse was associated a small chipped agate flake, and other similar flakes were obtained in the same deposits.

It is unfortunate that none of the mammalian bones can be more accurately determined, so that they might be identified with Narbada species found elsewhere in these deposits; but it is almost certain that they belong to the same epoch, and thus afford another instance of the association of the works of men with pleistocene mammals.

The list of mammals recorded from the older Jamna alluvium is now as follows:—

Semnopithecus, sp.
Euelephas namadicus (F and C)
Felis, sp.
Mus, sp.
Rhinoceros, sp.
Equus, sp.
Hippopotamus palaeindicus (F. and C)
Sus, sp.
Bubalus palaeindicus, (F. and C)
Bos, sp.
Portax, sp.
Antilope cervicapra (Pal.)

The Geology of Dalhousie, *North-West-Himalaya,—By Colonel* C. A. McMahon, *F. G. S. (with a map).*

In beauty of scenery, Dalhousie will bear favourable comparison with any other hill station in the Himalayas north of Darjiling. Richly wooded with oak, rhododendron, and the spruce and silver firs (*Abies smithiana* and *Picea webbiana*), an occasional deodar cedar, horse chestnut, or other deciduous tree, give variety to the foliage; whilst boldly jutting crags of gneiss and granite impart an element of wildness to the scene.

The view on all sides is almost equally good. Towards the plains, the clays and conglomerates of the Siwalik series, bright red in the glancing sun, may be seen rising in fantastic pinnacles next the Náhan sandstones; and then fading away in soft undulations, the warm green of the *Pinus longifolia*, with which they are clad, blending into the deep blue of the distant horizon, where the rivers Rávi, Chaki, and Biás, glow like streaks of molten silver in the glory of the setting sun. On a clear day, after heavy rain, the Chináb may also be seen in the far distance.

Towards the north one looks down upon a perfect labyrinth of mountains, whilst snowy peaks, 21,000 feet high, shut in the view.

The Dhulár Dhár (Dhauladhár) range ends somewhat abruptly at Dalhousie, where it attains an elevation of 9,103 feet above the sea. On the east, north, and west of Dainkund, the river Rávi flows, in its course to the plains, at an elevation of 3,033 feet at Chamba, and of about 2,260 feet near Kairi. As the elevation of the district embraced in this paper ranges from 9,200 to 2,200 feet above the sea, it will be readily understood that the ground is difficult to traverse; and that it would have been impossible for me, with the limited time at my disposal, to have followed throughout its entire length the line of out-crop of each of the rock series described. I have done so, however, to some extent, and have made, map in hand, so many traverses at right angles to the strike, that the accompanying map may be relied on. Until we have a more accurate map to work with, it would be mere waste of time to attempt to mark the boundaries of the different series in closer detail than I have done.

As it forms no part of the object of this paper to describe the tertiary series, I have only roughly sketched in the boundary line between the Siwaliks and the Náhans. I note, however, in passing that the Siwalik conglomerates contain numerous pebbles and boulders of the granitoid gneiss of the Dhulárdhár and of the trap, about to be described, from which it is clear that both these series were exposed when the Siwaliks were laid down.

The Volcanic Series.

A considerable thickness of trap is found in abrupt contact with the rocks of tertiary age all along the line. The trap is of compact texture and of greenish-gray colour on its fractured surface, with occasional purplish patches in it. It usually weathers from a light brown to a rusty brown colour; but sometimes it varies from sage green to a purplish neutral tint. The sage green variety scarcely weathers at all.

Amygdules abound near the upper and lower boundaries of the rock, and are occasionally to be seen in the more central portions. There are four varieties of these amygdules,—white and red, and white centres with red borders, and green centres with red borders. The two first mentioned are the most common. The amygdules are of moderate size. The rock gives no surface indication of bedding.

At page 607 of the Manual of the Geology of India, it was suggested that the trappean rocks of the Lower Himalayas[1] are of post-nummulitic age; the fact that the trap rarely penetrates the tertiary rocks is noted, and the question is asked, "Can the explanation of this apparent anomaly be that the origin of this intrusive rock is rather innate than hypogene?" The rocks to which these remarks would be applicable must, I consider, be different from those now under consideration.

Very similar rocks occur in Kashmir, and from Mr. Lydekker's description of them,[2]—from the few specimens sent me for microscopic examination,[3] and from their mode of occurrence,—I think they represent the traps under consideration. At first Mr. Lydekker seemed disposed to consider the Kashmir traps to be of metamorphic origin,[4] but he gradually came to the conclusion that they are "truly eruptive rocks.[5]"

A microscopical examination of thin slices of the traps described in this paper has quite satisfied me that they are more or less altered lavas. I reserve the further discussion of this branch of the subject for a subsequent paper which I propose to devote to microscopic petrology.

In the Dalhousie area these ancient lavas attain their greatest thickness between Nagali and Kande (Kandao), and the ridge running thence in a northward direction down to the Rávi is composed of them. Beyond the river the band narrows, and beyond Kairi bends sharply round to the west. The last I saw of them in that direction was in the bed of the river which flows into the Rávi at Kairi, and forms the boundary between the Kashmir and Chamba states. I have not had an opportunity of exploring the country over the Kashmir border. The climbing along the bed of this river at the point indicated is very difficult, and I do not recommend it to any one who is not a good cragsman. In its southerly extension, the trap widens somewhat at the elbow-like bend between Lahled (Lalaid) and Chambi, and from thence it gradually narrows until it becomes very thin at the toll-bar gate below the Mámul travellers' bungalow. It is here much crushed and rotten, and is partly buried under talus. It is seen in good condition further down, between Butoli (Patoli) and Auhar (Aur), and the stream running down from Mámul to the Chaki, follows its course for a considerable distance.

The boundary between the trap and the Náhan beds is probably a faulted one. The strata of the Náhan sandstones are often obscured by vegetation, but whenever I have had an opportunity of observing the dip near the point of contact, it has been perpendicular or nearly so.

[1] *i.e.*, the lower mountains including and east of the Simla region
[2] Records, Vols. IX, XI, and XIV. [3] Records, XI, 36. [4] Records, IX, 160.
[5] Records, XIV, 28.

In the Chuári (Chaohari) section, the trap is in contact with the conglomerates of the Siwalik series, the Náhans having probably been cut off by the fault.

The age of the trap will best be considered in connection with the next series.

The Carboniferous Limestone Series.

The rock immediately in contact with the trap along its eastern boundary is a quartzite, for the most part of white colour, as trans-Rávi near Kairi. There follows a thick series of shales and limestones, until the gneiss, which bounds this series on the east, is reached. Next the gneiss the rocks consist of a dark micaceous slate something between a shale and a schist, which disintegrates into a black "crush rock," exactly similar to the "crush rock" of the Simla area. A good and an extensive example of this rock may be seen on the descent from Dalhousie to Sherpur (Sairpur). It is here, especially when wet, almost coal black. This dark slaty rock is not confined to the eastern boundary of the series. I have also seen it at or near the western boundary, as in the river bed trans-Rávi, north of Kairi.

Occasionally limestone is seen within a few yards of the gneiss, and apparently in actual contact with it. An instance of this may be seen in the Chuári section, where the limestone which is as usual of dark blue colour, is subcrystalline and contains cubes of iron pyrites.

One of the best sections of the limestone series is, I think, to be obtained on the descent from Dalhousie to Sandára. The gneiss is left a little to the east of Dhalog, then succeed the dark carbonaceous slates, which exhibit a hypometamorphism in the shape of micaceous glazing. Between this and the quartzite in contact with the trap, I counted four strong outcrops of dark-blue limestone, intercalated with blue slates. The limestone is in bands of from 200 to 250 feet broad, and in beds that rarely exceed 2 inches in thickness.

Along this section the dip of the gneiss varied from about E 11° S to SE, and the micaceous dark rocks from SSE to SE 11° E. The blue slates dipped first high W, then perpendicular, and finally returned to an E or E 11° S dip.

The limestone series, as a whole, dips into the gneiss all along the line.

I think the carbonaceous slaty rocks above described, which disintegrate under the action of water into black "cush rock," are identical with the "*infra*-Krol" slates of the Simla region, which, even in that area, contain "lenticular layers of limestone.[1]"

The series under consideration corresponds, I think, completely with the description of the Kiol group given by Mr. Lydekker.[2] At the bottom of that group there is a purple or white quartzite, and then follow black shales containing thin "bands of brittle coal," followed by dark-blue earthy limestone.

Mr. Lydekker at one time thought the Kiol, which he correlated with the Krol group, to be of carboniferous age,[3] but subsequently he concluded that both the Krol and the Kiol are "representatives of carboniferous and trias.[4] He noted that "some of the shales of the Kiol are much like those of the *infra*-Krol,[5]" and considered that the latter are probably of carboniferous age.[6]

[1] Memoirs, III, 39.
[2] Records, IX, 161.
[3] Records, XI, 43, 62; XIII, 64.
[4] Records, XIII, 66; XIV, 40.
[5] Records, XIII, 66.
[6] Records, XIII, 66.

In Kashmir, rocks of carboniferous age appear to pass by imperceptible degrees into those of the Trias;[1] but in the absence of fossils, from the fact that the black carbonaceous slates similar to those of the "*infra*-Krol" occur at both margins of the series, I see no reason to suppose that we have at Dalhousie representatives of more than the carboniferous series.

As the quartzite only occurs at one margin, namely, next the trap, and is never associated, in this area, with the black slates next the gneiss, there seems to be no room for the supposition that we have here a crushed anticlinal flexure and that the black slates are repeated.

I observe that in the description of the Kiol series, given at page 160, Vol IX, Records, a black shale is said to occur next the quartzite at the bottom of the series (*b*), and a black slate (*d*), without an accompanying quartzite, at the top. In this respect, also, there seems to be a complete correspondence between the Dalhousie and the Kiol series.

In some minor points the limestone series of Dalhousie corresponds with the *infra*-Krol and Krol groups. Sometimes pale-blue to bluish-white watery shales occur in the series, the iron in which oxydises on exposure to various shades of red, yellow, and brown, which colours, combined with the natural blue and white of the shales, perhaps represent Mr. Lydekker's "polychroic slates" of Kashmir.[2] Some of these biscuity shales remind me of the "*infra*-Krol" shales to be seen at Solan[3] and between the Chor mountain and the Giri.

In the Chuári section purple-red shales occur, which closely resemble those of the Chor mountain. They probably have their origin in volcanic dust deposited in water.

In many localities the limestones present a banded appearance, owing to slaty layers of varying thickness being intercalated with the thin beds of limestone; and as the latter usually yields to weathering more readily than the slaty layers, a ribbed appearance is produced. In the river bed, trans-Rávi, these slaty layers are lenticular and fragmentary, and produce a curious graphic appearance. I think it is to small fragments of this mud enclosed in the limestone that the pseudo-fossiliferous appearance, sometimes observed, is produced. I have observed enclosures in some of the Dalhousie limestones, which reminded me of the Kakarhatti rock.

I now pass on to consider the age of the trap and its relations to the limestone series, which I have given reasons for believing to be of carboniferous age.

At page 160, Vol. IX, Records, Mr. Lydekker describes the amygdaloids as overlying the Kiol series, which, we have seen, he considers to be of carbo-triassic age; but the series is represented as inverted. In Vol. XI, page 35, the amygdaloids of the Sind valley and Pir Panjál range are described as being of *infra*-carboniferous age; and at pages 40 and 49, they are classed as the "highest silurians." In Mr. Lydekker's last published paper[4] he gives many instances of the occurrence of the traps at the base of the carboniferous series (as, for instance, at pages 22, 24, 25, 26, and 28), but the following conclusion is arrived at:—"Assuming an eruptive origin for the traps of Kashmir, it would appear that

[1] Records, XIV, 34. [2] Records, XIII, 62. [3] Memoirs, III, 28. [4] Records, XIV, 1.

during the silurian period very considerable outflows of sub-marine trap were emitted, which were naturally of limited extent; that these outflows probably took place in several localities and at several distinct intervals of time. During the whole period of these eruptions continuous deposition of stratified material was taking place, the strata resulting from which became intimately mixed up and amalgamated with the trap, so that it is now extremely difficult, or impossible, to distinguish the different factors of the strata. In certain localities, as at Manisbal, the outflows of trap must have continued to take place during a part, or the whole, of the carboniferous period, and have rendered the rocks of that period also difficult of recognition."

The lava flow of Dalhousie must, from its position, either be of upper silurian or of upper or post-carboniferous age, and it is important to decide to which it belongs.

I think there are more grounds for believing that the traps of the Dalhousie area are of pre-carboniferous than of post-carboniferous age. There are difficulties in the way of believing that an overflow of lava in the Kashmir, Dalhousie, and Mandi areas lasted from middle or upper silurian times to the end of the carboniferous period. It would be remarkable if these ancient volcanoes continued to pour out, through so extended a period, one kind of lava only; and all that I yet know about these amygdaloidal traps leads me to believe them to be very homogeneous in their character. Moreover, if the lava flow lasted from the silurian to the close of the carboniferous period, one would expect to find substantial bands of trap included in that very thick series of limestones that pass by insensible degrees from the carboniferous into the trias, and the more so if the traps were, as suggested by Mr. Lydekker, of sub-marine origin, seeing that the limestones, in some instances at any rate, must have been laid down at no great distance from these ancient volcanoes. I am not aware, however, of any considerable lava flows having been interposed between the carboniferous and the triassic series in the lower Himalayan region.

The altered condition of the Dalhousie traps to a certain extent favours the theory of their being of great age; whilst the fact that the boulders of the trap buried in the Siwalik conglomerates exhibit the same phase of alteration as their parent rock negatives the idea of the alteration being the result of tangential pressure in tertiary times. A more important fact is that they occur below the quartzite band, which is the bottom rock of the Kiol group in Káshmír and of the Krol series in the Simla area.

An apparent difficulty occurs in the correlation of the Kiol to the Krol, from the fact that, in the Simla area, the black *infra*-Krol shales occur below the horizon of the Krol quartzite, whilst at Dalhousie and at Kiol the black slates occur above a quartzite. But I think this difficulty is apparent rather than real. The quartzites may not have been perfectly synchronous in both areas, for one thing; and for another, it is clear from the examination of the Dalhousie series and the recorded description of the Kiol rocks, that the period during which the carbonaceous element was deposited was a very extended one, for black slates are found at the top and bottom of the series; and therefore it seems not improbable that the formation of the carbonaceous material in the Simla region, set in and died out earlier in the carboniferous age than in the Dalhousie and Kiol regions.

If the above conclusions are sound, it follows that from the trap to the top of the limestone series we have a normal sequence of rocks, the carboniferous series resting conformably on the upper silurian or pre-carboniferous trap—both being faulted against the gneiss.

I can see nothing to countenance the idea that the metamorphism of the gneiss, about to be described, is due to the development of heat caused by the compression of strata in which the carboniferous limestone series was involved. Had heat sufficient for the transformation of sedimentary strata into a uniform bed of gneiss, 500 feet in thickness, been developed, I think the dark blue limestone within a few yards of the gneiss would have been much more changed than we find it is.

The junction of the limestone series with the gneiss must, it seems to me, be due either to faulting or to inversion. Something might be said in favour of the inversion hypothesis—it is the theory that naturally suggests itself at first, and when I began to explore the Dalhousie region I adopted it for a time. On the new cart road, a couple of miles on the Dalhousie side of the Duniára road-bungalow, the dark slates may be seen dipping under the gneiss, apparently conformably; and you may stand on the edge of the gneiss, on the ridge about 3 miles north of the Duniára bungalow, and note the black slates far below, at the opposite side of the khad or valley, cropping out about half a mile east of a line drawn north and south through the spot on which you are standing.

A section like this naturally suggests the idea of inversion, but I found this theory would not harmonize with the rest of my facts. If the inversion hypothesis were adopted, it would make the trap to be of post-carboniferous age, and it would put the white quartzite at the top, instead of in its proper place, at the bottom, of the limestone series.

In other ways I found it impossible to work the inversion hypothesis. For instance, one would have to account for the disappearance of all the rocks between the carboniferous series and the gneiss; and one could hardly suppose that extensive and deep erosion sufficient to have caused this would have stopped precisely at the gneiss all along the line—invariably removing everything above the gneiss, yet never cutting into or through it. For these and other reasons, I had to drop the inversion theory and adopt the hypothesis of faulting, against which I know of no serious objection.

If we suppose (and it seems a reasonable supposition) that the disturbances which caused the faults were prior to those which threw the strata into the synclinal and anticlinal flexures we now see, or that the compression of the rocks continued after the rupture of the faults, I can comprehend how a reverse fault with so great a throw was formed. This supposition may account for the curves observable in the trend of the fault; but if, as is suggested further on, a highly compressed anticlinal fold is situated in the gneiss of Dainkund, there will be less difficulty in understanding how the torsion observed in the strike of the gneiss was produced. The sharp minor curves in the boundary-line marked on the map are due to the fact that where the north-easterly dip of the carboniferous series and the gneiss are moderate, the line of outcrop in the deep, narrow valleys occurs further to the east than on the crests of the high steep ridges that run down from Dainkund.

The Silurian and Cambrian (?) Series.

The rock in contact with the carboniferous series, along its eastern boundary throughout the Dalhousie region, is gneiss. It is foliated and never granitoid. The gneiss is composed of quartz, orthoclase and biotite. I have noticed no muscovite or schorl in it, and at times its crystallization is imperfect. The gneiss forms a continuous band, and does not vary much in thickness, which is usually from 400 to 500 feet. From the ridge above Banatu (trans-Rávi), where it is seen stretching away in the direction of Mandoh (Maroh), its thickness remains steady, and it is well seen on the new cart-road south of Duniára, and on the ridge between Buliára and Kailu. It then thins considerably, and the outcrop on the bridle road north-east of Tula might easily be overlooked. On the eastern side of this ridge, however, it crops out in a prominent way on the old and now abandoned road running up to Naina Khad (Nina Kad). It is seen well at Hubár (Ubaur) and at Chuári, where it has regained its normal thickness.

Next the gneiss, comes a rather thick band of decided mica schists. It is thickest on the south bank of the Rávi, extending from the gneiss to near the stream east of Seru (Sairu). This mica schist shades rather rapidly into a series of slates and very fine-grained earthy sandstones, terminating next the granitoid gneiss in slates, which I believe represent the "Simla slates."

An instructive and convenient section is that from the Therah Mall at Dalhousie along the cart-road to Banikhet (Banketra), and thence along the road to Dhalóg. I collected a series of hand specimens along this road for macroscopical and microscopical examination, and the series consist of the following, beginning with the rocks next the granitoid gneiss:—

1. A fine-grained quartz schist, with very minute prisms of hornblende disseminated through it.
2. A fine-grained quartz schist, containing minute prisms of hornblende and microscopic flakes of mica.
3. A very fine-grained earthy sandstone, somewhat schistose in aspect; a few grains of mica are to be seen in it here and there.
4. A very fine-grained earthy sandstone—very earthy looking.
5. A very fine-grained earthy sandstone—extremely earthy looking. A few minute prisms of hornblende are to be seen in it under the microscope.
6. A similar rock, but less earthy looking.
7. A fine-grained micaceous schist. Microscopic grains of a greenish-white mica, and few minute crystals of hornblende disseminated through it.
8. A fine-grained slaty rock.
9. A fine-grained earthy sandstone.
10. A fine-grained slaty rock.

11. A slate with a slight micaceous glaze.
12. A soft flaky shale, with a slight micaceous glase.
13. An ordinary slate of pale-blue colour.
14. An ordinary slate of darker colour.
15. An ordinary slate of pale-bluish grey.
16. Soft splintery shales of pale-bluish colour.
17. A similar rock, but more indurated.
18. A white wafery shale.
19. A whitish-grey slaty rock, with flakes of white mica here and there.
20. A grey silicious schist.
21. A mica schist— lenticular granules of quartz being coated with silky white micaceous material.
22. The decided mica schists of Banikhet. There are some hundreds of feet of this rock and then follows—
23. Four hundred or five hundred feet of gneiss.

In other sections (as, for instance, at Chuári) clay slates take the place of the fine-grained earthy sandstones. Within a few miles of Dalhousie itself, on the road to Bakloh, good slates are quarried quite close to the granitoid gneiss.

Everywhere the beds immediately in contact with the "granitoid gneiss," for a distance that varies in different sections, exhibit more or less hypometamorphism.

Along a section taken in a westerly direction from Dalhousie the average dip of the silurian beds is NE; but it varies locally from NE 11° N to NE 11° E. As a whole, the series dips into the granitoid gneiss all along the line, and, judging superficially from appearances, one would say that it dipped under the gneiss.

Mr. Medlicott, in vol. III, p. 65, Memoirs, describes the rocks next the granitoid gneiss at Dalhousie as follows:—"For about 50 feet from the granite, the schists exhibit a very marked increase in induration, acquiring a close-grained crystalloid texture. Near the contact, irregular small veins of the granitoid rock are included in this hard contact rock; yet the junction with the main mass is perfectly sharp, indicating no approach to an amalgamation of their ingredients." And in the page first quoted, he wrote: "In the descending section to the west of Dalhousie, the schistose characters become again more and more developed; at Banketra we find decided mica schists."

I think we have here the clue to the interpretation of this section. Broadly speaking, we have slates next the granitoid gneiss, and then silicious and slaty rocks passing into decided mica schists, resting on a broad band of gneiss, from 400 to 500 feet thick. In other words, we have a descending series, beginning with the representatives of the "Simla slates" and passing into the lower silurians[1];—this descending series resting on gneiss on the one side, and faulted against gneiss on the other.

Mention is made in the *Manual of the Geology of India*,[2] on the authority

[1] In my paper on the Chamba and Dalhousie section (Records XIV, p. 308), I have stated the grounds which exist for holding the Simla slates to be middle, and the beds below them lower silurians.

[2] Page 633.

of Dr. Stoliczka's observations in Ladak, of a "newer gneiss" of syenitic mineral character. I do not think that the second band of gneiss described in these pages represents the newer gneiss. In the first place it is not syenitic, and in the second place I think there are difficulties in the way of believing that we have one series of rocks from the granitoid gneiss of Dainkund to the band of foliated gneiss to the west of it. Were this supposition to be adopted, the granitoid gneiss would of course come in near the bottom of the series, whilst the "newer gneiss" would form the top, the whole being inverted.

This view would require a concealed anticlinal flexure in the granitoid gneiss of Dainkund—a fold so compressed as to produce conformity of dip on both sides of the anticline. I have kept the possibility of this being the case before me, but have not, as yet, discovered any evidence to support the hypothesis. I met with no trace of a newer gneiss between the gneiss of Dainkund and that of Pángi, though in this long synclinal flexure rocks from the "carbo-triassic" to the 'central gneiss' are exposed.

Again, on the supposition that the granitoid gneiss of Dainkund is "older" than the band of gneiss to the west of it, we should have to explain the total absence of the lower silurian beds between the "Simla slates" and the older gneiss; and the very remarkable phenomena would be presented to us of highly metamorphosed rocks at the top and bottom of the series with very slightly metamorphosed rocks in the middle.

The study of Himalayan rocks has led me to the conviction that the only way out of the labyrinth is to keep in view the principle that, as a general rule, the extent of metamorphism affords an indication of the relative age of ancient rocks. Undoubtedly there are numerous exceptions to this general rule. "Selective metamorphism" is a powerful factor, and its operations must ever be kept in mind. The right interpretation of the facts observed in Himalayan geology is surrounded by many difficulties, inasmuch as every possible kind of metamorphism is rampant in this region; but still, I think, the principle advocated above is the one that will, if followed, lead to the fewest mistakes.

Having arrived at this conviction by independent study, I was interested to find it fortified by Dr. Callaway's remarks in his recent paper in the *Geological Magazine* on "How to work in the Archæan rocks." He writes[1]:—

"In studying the lithology of a formation, its *degree of metamorphism* is an important factor in the evidence. Sufficient material has not been collected to form the basis of a theory; but, so far at least as England and Wales are concerned, the researches of the last few years lend some support to the opinion that regional metamorphism is found only in Archæan rocks, and that the degree of alteration is proportional to the antiquity of the group."

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"There would also appear to be no *a priori* reason why regional metamorphism should not also occur in rocks of any age; and in the above remarks it is only contended that there are some grounds for constructing an empirical rule applicable only, so far as present observations go, to a certain area."

[1] *Geological Magazine*, Vol. VIII. (1881), pp. 423, 425.

Professor Bonney's observations in Vol. VII of the *Geological Magazine*, page 542, are also pertinent. He writes :—

"With our present knowledge, extreme caution is doubtless required in drawing an inference as to the age of a rock from its stage of metamorphism. At the same time all the evidence which we possess points to the conclusion that extensive regional metamorphism has only taken place in rocks of great geological age, and that the current statements about highly altered secondary and even tertiary rocks in the Alps are in many cases entirely erroneous and in all need confirmation. Thus, in the case of the Alpine schists, which as a rule are more highly altered than any rock in Britain known to be of Cambrian or post-Cambrian age, I should agree with some of the more modern continental geologists in regarding them as very old and possibly pre-Cambrian."

Holding the views expressed above, I think it improbable that we have presented to us here a normal sequence of beds beginning with a rock of perfect granitic structure, followed by clay slates and other little altered rocks and ending with decided mica schists and gneiss as its top beds. I think the more probable and reasonable explanation is that a descending series of rocks from the slates to the gneiss has been faulted against the granitoid gneiss.

The supposition that the two beds of gneiss form the sides of an anticlinal flexure, seems inadmissible on similar grounds; for in this case the slates and other slightly altered beds would have to be put below the perfectly metamorphosed granitoid gneiss.

The hypothesis that the two beds of gneiss form a synclinal flexure, seems to me to be objectionable; for in this case the rocks next the gneiss on both wings of the flexure ought to be similar, whereas they are unlike each other. I am ready to admit the possibility of an anticlinal fold having taken place, in which case the western outcrop of gneiss would form the western wing of the corresponding syncline; but if this hypothesis were to be adopted, we should have to suppose that the inverted wing of the syncline had been squeezed out of the section. It does not seem necessary to call in the aid of a very complicated fault of this nature; a simple step-fault will, I think, in some respects best explain the section.

The fault hypothesis is the only one that, in my opinion, satisfactorily explains the facts. We have, I think, a repetition of what we have found reason to believe took place in the case of the carboniferous series, namely, a normal sequence of rocks faulted against the gneiss.

And if we accept the existence of these great faults immediately over a region of ancient volcanic activity, evidenced even in our own day by an occasional earthquake and by the presence of numerous hot springs in the trap and gneiss areas, may we not explain the hypometamorphism of the silurian and carboniferous slates along these lines of fault, by the action of superheated steam and water and acid vapours finding access to them along these fissures for some time after the faulting had taken place? No microscopist who has studied the metamorphism of igneous rocks can doubt the power of heated water or steam to effect gradual changes in the rocks subjected to their action; and the fact that the hypometamorphism of the silurian and carboniferous rocks, as a rule, runs with lines which, on other grounds, I have seen reason to believe to be lines of fault, strongly favours the supposition that the hypometamorphism described is due to these agencies. It would be a curious coincidence, indeed, if tangential pressure produced metamorphism along these lines and left the intermediate rocks untouched.

The "Central Gneiss."

Between Dalhousie and Chamba the granitoid gneiss attains a thickness of 6½ miles. It retains this breadth in its south-easterly extension; but, in the opposite direction, it rapidly narrows as the river Rávi is approached. In the Memoirs of the Geological Survey,[1] it was noted that down the spur, running between Panjao and Chata towards the river, "the band contracts, and to all appearance, as seen from this place, it becomes extinct before reaching the Rávi, on the right bank of which there seems to be a continuous section of thin-bedded crumbling strata;" and the conclusion was drawn that the "central gneiss" had there "ended completely and abruptly.[2]"

The trans-Rávi section has now been explored for the first time, and I find that though the gneiss dwindles to a very thin band, it does not die out. Above the road, running from Júnd (Juind) to Bhale (Balai), the outcrop actually visible is not more than 100 feet in thickness. Where the outcrop crosses the river above Bhale, I measured 250 feet of it. In its north-westerly course the gneiss forms the crest of the high ridge above Sere (Serai). The last I saw of it was at Kandan Devi, where it leaves the crest of the ridge and strikes in the direction of Sapra (Sipra). Along this ridge it attains a width of about 500 feet. The outcrop looks thicker on the map because the N E dip of the gneiss coincides with the slope of the N E side of the ridge.

Speaking generally, the gneiss is an ordinary foliated gneiss along both margins of its outcrop, and here the bedding, which conforms to the normal dip and strike of the rock series associated with it, is quite distinct. The gneiss gradually passes into a granitoid rock, in which evidence of foliation may usually be traced; and, although joints are numerous, true bedding is often obliterated. The granitoid gneiss is highly porphyritic, and is undistinguishable from, and doubtless is identical with, the "central gneiss." Towards the centre of the mass the porphyritic appearance dies out, and along the ridge of Dainkund the rock passes into a fine-grained and perfect granite. There are transitional forms between this and the porphyritic granitoid gneiss; that is to say, we have here and there a more or less porphyritic rock which is perfectly granitic. On the road to Chil the matrix becomes so fine-grained in places that the rock assumes almost the outward aspect of a felspar porphyry.

Where the mass begins to narrow in its north-westerly direction, the rock at the same time gradually loses its granitoid character and passes into an ordinary foliated gneiss, in which porphyritic crystals are, generally speaking, sparse or wanting.

At times the porphyritic granite obliterates the foliated, stratified gneiss, even at the margins of its outcrop, and intrudes into the adjoining schists. Instances of intrusive veins at Dalhousie were described by Mr. Medlicott in the passage

[1] Memoirs, III, 64. [2] Manual, page 633.

already quoted from page 65 of his Memoir. I may mention another instance at Dalhousie, on the cart road near the Bulls Head hotel, where the granite is seen to cut through the beds in contact with it for 2 or 3 feet. How deep it goes, cannot be seen owing to the dense vegetation below the road.

Trans-Rávi, on the ridge north of Banatu, intrusive veins are also to be seen in the schists close to the gneiss, and here these veins are distinctly porphyritic, indicating that the intruded rock was squeezed into the schistose beds in a viscid and imperfectly fused condition. But it was in the Chuári section that I observed the most numerous instances of the intrusion of the schists by the porphyritic granite. Here the latter has been profusely squeezed between the beds of schists for a considerable distance from their junction with the crystalline rock, and in some instances the porphyritic granite has cut through them.

The mineralogical characters of the gneiss will be described more in detail in a subsequent paper on the microscopic petrology of Dalhousie; but I note in passing that, viewed microscopically, the rock is seen to contain orthoclose, quartz, biotite, and muscovite. In the granitic varieties, schorl, in minute or moderate-sized crystals, is pretty abundant. I have also noticed some small garnets, in which respect the rock also corresponds with the "central gneiss" of the Sutlej valley.

The rock varies very much in texture within short distances. Some of it breaks without much difficulty, and then the workman passes suddenly to an indurated mass that defies the power of the hammer. The weathering of the rock, also, is often peculiar. Judging from superficial appearances on road sides, one might readily imagine that intrusive dykes were frequent and that they had caught up boulders and blocks of gneiss in their passage. Dykes I believe there are, but the appearances I allude to are, I think, due to weathering and arise from variations in the texture of the rock.

Having described the general stratigraphical and lithological characters of the "central gneiss," I pass on to consider the causes of the great changes observable in its texture and structure. I allude principally to its passage from an ordinary foliated gneiss through a somewhat coarse-grained porphyritic rock (in which the porphyritic crystals of felspar attain a length of 3½ inches) into a fine-grained non-porphyritic granite.

It has been somewhat fashionable in the geological world of late years to attribute the metamorphism of mountain regions to the heat developed by the compression of strata which accompanies mountain formation. That metamorphism, to a certain extent at any rate, is produced in this way I do not doubt, and to this cause may possibly be due (though I have suggested another explanation in the preceding pages) the hypometamorphism of some of the silurian and carboniferous beds; but I do not see sufficient grounds for believing that the perfect metamorphism of the rocks now under consideration can be attributed to this cause.

If you bend a stick across your knee with sufficient force, it will break along the axis of greatest strain, which will be over the region of the knee. Now, a glance at the map will show that, where the Rávi and Siul rivers cut across them, the gneiss bands, with the included silurians, have been bent, as you would bend a stick across your knee. The strain at this point must surely have been at its maximum, and yet the westerly band of gneiss preserves its normal thickness with a steady indifference to the Mallet theory, whilst the easterly band of gneiss narrows from 6½ miles to 250 feet!

But if it be objected that the differences observable in the degree of metamorphism is due rather to innate conditions—variations in the amount of water contained in the beds and the like—rather than to fluctuations in the intensity of the squeeze, I reply that there are difficulties in the way of explaining the metamorphism of the particular rocks before us—the granite, gneiss, mica schists and trap of the Dalhousie area—by this theory. The tangential pressure which caused the geosynclinal to assume the folds and contortions now to be seen in the Himalayas is generally believed to have been caused by disturbances in later tertiary times, but we have seen that the trap and granitoid gneiss existed as such when the Siwaliks were laid down, and Mr. Lydekker found granitoid gneiss boulders, which he believed to be identical with the central gneiss, in slates of the Pángi valley of presumably upper silurian age.

But a still more serious objection to the application of the Mallet theory to the facts before us occurs to me. It is usually noted in text books that crystallization is of coarser grain in the centre of igneous masses than at their sides, and the reason assigned is that these masses cooled more rapidly at the sides than in the centre. The following extracts are taken from recent papers by experienced observers. Professor Geikie in his memoir on the Carboniferous Volcanic Rocks of the Firth of Forth writes as follows of intrusive sheets and dykes[1]—"A diminution in the size of the crystalline constituents may be traced not only "at the base, but also at the top of a sheet, or at any intermediate portion which "has come in contact with a large mass of the surrounding rock."

Again Professor Heddle in his 5th Chapter on the Mineralogy of Scotland,[1] as the result of his extensive experience, states that in the case of the plugging of pre-existent rents with the same ingredients as the rock mass itself, the structure is *smaller* than that of the rock mass in the case of *contemporaneous* plugs; whilst in veins of *exfiltration* the structure is *larger* than that of the containing rock. These generalizations were, of course, made with special reference to the rocks of Scotland, but they are important and suggestive.

I presume that those who would attempt to explain the metamorphism of the "central gneiss" by the application of the tangential pressure theory would argue that those parts of the gneiss at Dalhousie which exhibit the most perfect granitic structure are those in which the greatest heat was developed. These places coincide, in the main, with the centre of the mass; and as the parts where the greatest heat was developed must have cooled the slowest, the crystals of which the resulting rock is composed ought, according to our present information on these subjects, to have been larger in the centre of the mass than towards the sides, whereas the reverse is the case.

A precisely similar objection to that taken above seems to me to stand in the way of the hypothesis that the extreme metamorphism of the central parts of the

[1] Transactions of the Royal Society of Edinburgh, Vol. XXIX, 475, and p. 1.

mass and the comparatively imperfect metamorphism of the margins, is due to the plutonic heat from below having been greater at some points than at others. The structure of those parts which received the greatest heat and cooled more slowly ought, in masses whose granitic structure shows that there was perfect freedom of molecular and crystallographic action, to have been of coarser grain than those portions which received less heat and consequently cooled more rapidly; but this is not the case.

The explanation that satisfies my mind the most is that the intense metamorphism of the "central gneiss" has been principally produced by granitic intrusion at a great depth below the surface; and that the perfectly granitic portion is the intrusive granite itself.

In Auvergne[1] we know that, in the case of the numerous volcanoes in the neighbourhood of Clermont Ferrand, the lava pierced through a stratum of granitic gneiss before it overflowed at the surface. I can see no reason why what took place near the surface in Auvergne may not have taken place, in other localities, at a greater depth below the surface. It is freely admitted by many leading geologists that an acid igneous rock consolidated at a great depth below the surface would form granite, for a perfect transition may be traced from granite, on the one hand, to acid lavas, on the other. "No one," writes Professor Judd at page 145 of his recent work on volcanoes, "who has carefully "studied the appearances presented by volcanic mountains in different stages "of dissection, by the action of denuding forces, can avoid recognising these "great granitic masses, as the cooled reservoirs from which volcanoes have in all "probability been supplied during earlier periods of the earth's history." And again, at page 256 he writes:—"A careful consideration of all the facts of the case "leads to the conclusion that when pumice, obsidian, and rhyolite are now being "ejected at the surface, the materials which form these substances are, at various "depths in the earth's interior, slowly consolidating in the form of quartz-felsite, "granite porphyry and granite."

Now, if we suppose that the Dalhousie gneiss was buried at great depth and was in consequence exposed to considerable heat when an acid igneous rock passed through it in its passage upwards, it seems to me that when they cooled down they might become so welded together as to render it impossible to say when the one began and the other ended. In the case supposed we should have, acting on the gneiss, not only the heat caused by contact with the intrusive igneous rock, and the plutonic heat of the earth itself, but the gneiss would probably be permeated by steam at high pressure or intensely heated water holding some of the mineral constituents of the igneous rock in solution. I can, therefore, readily imagine that under the conditions described a blending together of the granite and the gneiss would result, and that the latter would, for some distance from its contact with the granite, partake of its mineral character.

For this reason I do not think that the fact that I have not observed muscovite, schorl or garnets in the westerly band of gneiss proves that the latter does not really represent the more perfectly crystallised gneiss further east.

[1] See p. 361, "Scrope on Volcanoes" and his "Volcanoes, Central France," at large.

The westerly band is a comparatively imperfectly metamorphosed rock and had its metamorphism proceeded further, and had it been brought into closer contact with the rising granite, it would probably have developed all the minerals found in the granitoid gneiss Even in some portions of the latter the muscovite, schorl and garnets are sparse or wanting.

One of the principal characteristics of the "central gneiss" of the Satlej and lower Spiti valleys, and elsewhere in the Himalayas, is that it is everywhere more or less riddled by intrusive dykes and veins of white oligoclase granite. Sometimes these veins and dykes are most profuse. I remember one spot in particular on the Para river, between Lari and Chango, near the border of Chinese Tibet, regarding which I made the following entry in my journal:—"Before starting 'I examined the rocks at Jangzam. Those up the river I found to be gneiss, "nearly obliterated by granite;" the partial obliteration having been caused by the number and close proximity to each other of the intrusive veins. The only difference in the two cases seems to me to be this, that in the area now described the granitic intrusion was probably more intense, the gneiss was more heated and rendered more plastic, and the two rocks were better blended together. The white oligoclase granite of the Satlej and Spiti areas possibly marks a somewhat later stage of the eruptions which effected the conversion of the gneiss into a granitoid rock.

Even in the Dalhousie area there is sometimes a sharp line of division observable between the fine-grained and the porphyritic granite. A good example of this is to be seen at the top of the Chuári pass.

I am not only disposed to hold that the fine-grained, non-porphyritic portions of the "central gneiss" seen at Dalhousie is as truly an "igneous" rock as any igneous rock can be; but I have been gradually forced into the conviction that portions, at any rate, of the porphyritic variety are to *some extent* intrusive.

In the case of a gneiss exposed to sufficient moist heat to allow of a certain freedom of molecular action, I can imagine the felspar "eyes" growing by the accretion of felspar molecules into more or less perfect crystals with well-developed faces and angles; but I think it would be difficult to account for the principal axes of these crystals pointing indifferently in all directions, as they do in the granitoid gneiss, without supposing that the plastic mass had been set in motion. The supposition that this peculiarity has been produced by motion is supported by other facts. In the Chuári section I noticed that, not only in the veins intruded into the schists, but also in the granitoid rock, the solid angles of what had apparently once been well-formed crystals of felspar were rounded off as if by abrasion; whilst there were numerous instances of other orthoclase crystals having been rolled up into masses, sections of which were about the size and shape of a crown piece. These seemed to me to be indications that after the orthoclase crystals had been formed, they had subsequently been subjected to great heat and pressure, and had been rolled along in a viscid stream containing numbers of similar crystals.

That porphyritic crystals have often been transported from one place to another after their formation has long been known to microscopists. The evident fragmentary condition of some porphyritic crystals in lavas is held to be evidence of this; whilst the liquid and other cavities they sometimes contain are also evidence in favour of the porphyritic crystals having been formed before they reached the surface.

I may mention, in connection with this subject, that, when I visited the crater of Vesuvius in 1878, I obtained some red-hot lava by pushing a stick into the flowing stream. This I cooled suddenly by pouring claret over it, water not being at hand; and I found, on having slices made for microscopic examination, that the lava contained numerous good-sized crystals of augite and leucite imbedded in the glassy base. Doubtless, the large crystals had been transported from hidden depths below the crater.

Another piece of evidence which goes to prove that much of the porphyritic granite of the Dalhousie area is (to a certain extent, at any rate) intrusive, is that fragments of schists are included in it. For some time I regarded these objects as concretionary in origin; but the conclusion was ultimately forced on me that they are true fragments of the adjoining schists, caught up by the granite in its passage through them. They are more numerous close to the schists than away from them; they closely resemble the schists in colour and material, and in the Chuári section, where the porphyritic granite has been squeezed into and between the schistose beds, fragments of schists may be seen caught in the act, so to speak, of being broken off.

Some of the included pieces—even those seen a long way from the junction of the granite and the schists—seemed to me of undoubted fragmentary origin. One, for instance, which I noticed in the Chuári section, was a long splinter 2 feet 4 inches long and 5½ inches wide at the thickest end. In its splintery ends it seemed to give clear evidence of having been torn from its parent rock. It stood out sharply from the granite, and it was fractured transversely in several places, the cracks not penetrating into the granite.

Whilst, however, I think there are many good reasons for believing that the extreme metamorphism of much of the "central gneiss" is due to granitic intrusion, and that intruded masses have been dovetailed into the gneiss, I do not think the sudden expansion of the gneiss from a width of 100 feet to nearly 7 miles is wholly due to the protrusion of viscid masses of an acid igneous rock into beds of pre-existing gneiss. Considering that the granitoid gneiss retains its great thickness in its south-easterly extension for so great a distance, its sudden attenuation north of the Rávi is remarkable. The silurian beds between the two outcrops of gneiss maintain much the same average thickness throughout; and, as I have seen reason to believe, on other grounds, that a fault occurs along the margin of the gneiss at its junction with the slates, it seems to me probable that the sudden attenuation of the gneiss towards the north-west may be due primarily to faulting.

Glaciation.

The spur on which the Mámul travellers' bungalow stands, near the military station of Bakloh, at an elevation of about 4,740 feet above the sea, puzzled me for some time. The crest of this ridge is principally composed of granitoid gneiss absolutely identical with that of Dainkund. The trap bounds it on the south, but it is completely surrounded on other sides by the limestones and slates of the carboniferous series. Further investigation showed that the crest of the opposite spur is also covered with large boulders of granitoid gneiss, resting on carboniferous rocks. After several careful examinations of the locality, I found that the facts could not be explained by intrusion or faulting, and I came to the conclusion that we can have here nothing else than the remains of an old moraine.

The supposition of a landslip seems inadmissible, for the deposit is on the very crest of a spur, and high ridges and peaks intervene between it and the granitoid gneiss of Dainkund.

The fragments of granitoid gneiss of which the crest of the Mámul ridge is principally composed, are of considerable size, being as much as 12 feet high by 12 feet long. They are evidently fragmentary, and some have apparently been more or less rounded before they fell into place. Sometimes the blocks are closely packed together, and look like rocks *in situ*. In other places the fragments are evidently embedded in earth. A small landslip near the tollbar exposed a good example of this. The granitoid gneiss, moreover, is not alone; fragments of schists and quartzites, of various sizes, up to 3 feet in diameter, are scattered in profusion over the surface, and are fixed into the hillside. They are all fragments of rocks found between Mámul and Dainkund. A roadside cutting at one place gives an instructive section. It is about 10 feet high, and is cut down straight as a wall. The crest of the spur there is seen to be composed of boulders of granitoid gneiss and of schists and shales of various sizes buried in a matrix of unstratified earth.

The Mámul moraine is not the only decided instance of ice action I have seen within the Dalhousie area. In the valley formed by the small stream that runs down from Kud to Hubár, below Bariara, countless huge blocks of granitoid gneiss are thickly scattered on the surface of the ground. One of them, which I measured, I found to be 29 feet long, and thick and high in proportion. Higher up the valley, but still a long way from the granitoid gneiss, I noticed another, 42′ × 25′ × 30′ or 40′. The puny stream that takes its rise at the head of this small valley could not have transported such blocks had it formerly been fifty times as large as it now is. At Kud itself, the jutting ends of the strata, which crop out nearly at right-angles to the course of the stream, have been evidently sculptured by ice action, and stand out like the rounded bastion of a fort. The rounded portions are high above the stream, and are quite inaccessible, so that I could not see whether they are scored and striated.

Conclusion.

Professor Judd, in his recent work on volcanoes, suggests the existence of a general correspondence between the course of events which ushered in the birth of the Alps and the Himalayas; and I think the study of the geology of Dalhousie furnishes some additional evidence of this correspondence.

Professor Judd's sketch of the history of the Alps may be briefly epitomised as follows:—"The first stage was the opening of a number of fissures running

along a line near to that at which, at a long subsequent period, the elevation of the mountain masses took place."[1] * * * "From the great fissures opened in Permian times along this line of weakness, great quantities of lava, scoriæ and tuff were poured out, and these accumulated to form great volcanic mountains, which we can now only study at a few isolated spots.

"The 2nd stage consisted in a general sinking of the surface along this line of weakness in the earth's crust, the existence of which had been betrayed by the formation of fissures and the eruption of volcanic rocks." * * * The volcanic energy which had been manifested with such violence during the Permian period, does not appear to have died out altogether during the succeeding Triassic period.

"The subsidence was continued almost without interruption to the Nummulitic period.

"The third stage commenced in Oligocene times. It consisted in a series of movements affecting the parts of the earth's crust on either side of the line of weakness which had first exhibited itself in Permian times. By these movements a series of tangential strains were produced, which resulted in the violent crushing, folding, and crumpling of the sedimentary materials composing the geosynclinal."

If the views I have propounded in this paper are correct, it follows that a series of grand volcanic movements took place along a line coinciding with the direction of the axis of the Himalayas. These movements commenced probably in early silurian times, and continued until the close of that period, after which they became comparatively insignificant. There followed a long period of subsidence during which a great series of limestones were laid down, which extended from the carboniferous to the triassic period. In the Spiti region the subsidence appears to have lasted until the cretaceous period, whilst part of the Simla area was under the nummulitic sea in eocene times. Then followed the final series of movements which threw the strata, old and new, into a series of folds, the axes of which have a general N. W. and S. E. trend.

I have not attempted to enter into any details in the above brief sketch, as my only object in making it, is to draw attention to the fact that, as in the Alps, so in this region of the Himalayas, a long period of subsidence was preceded by great volcanic activity.

Note on remains of palm leaves *from the* (tertiary) Murree *and* Kasauli beds in India, *by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India* (with plate).

There is as yet very little on record upon tertiary plants from India. The only attempt at an identification of such fossils is contained in Mr. H. B. Medlicott's Memoir on Sub-Himalayan rocks of North-Western India,[2] wherein,

[1] Page 292.

[2] Memoirs, G. S. I., Vol. III, pt. 2.

on pp. 97—99, Dr. Kane communicated the results of his examination of a small collection of tertiary leaves collected by Mr. Medlicott in the Kasauli beds.

There is also in our collections a small series of tertiary leaves from Burmah, which, so far as I know, have not yet been identified. All these leaves will have to be thoroughly examined and compared with extra-Indian tertiary plants before they can be figured and described.

On the present occasion it is my object to notice especially one form, about the identification of which there appears very little doubt, and which is of peculiar interest on account of its wide distribution in extra-Indian tertiary rocks. My attention was directed to it by a specimen brought last season by Mr. Lydekker from the Murree beds in Northern Punjab,[1] consisting of red sandy shale and containing leaf impressions, which are easily recognised as being of palm leaves. My first note (given to Mr. Lydekker) about them was that they are "very close to, probably identical with, *Sabal major*."

There are impressions on both sides of the specimen, both belonging apparently to the same kind of leaf. On one side the impression represents the lower portion of the leaf (see fig. 1), and exhibits distinctly the fan-shaped form, as can be seen from the radiating arrangement of the ridges and furrows of the plaited leaf, the parallel simple veins on the plaits also being distinctly seen. The impression on the other side (fig. 2) represents more an upper portion of the leaf, showing, however, also the same characters as the other one.

If we now turn to the identification of the fossils, we find that they agree best with the fossil palm, now generally known as *Sabal major*, Heer, of which good figures are given in Prof. Heer's Flora tert. Helvetiæ[2] and in Prof. Ettingshausen's fossil Flora of Bilin in Bohemia.[3] It is figured as *Flabellaria major* in Unger's Chloris protogæa[4] and in Ettingshausen's fossil Flora of Hæring.[5]

Count Sternberg's *Flabellaria rapifolia*[6] is by Schimper placed with this species also, while Ettingshausen's *Sabal rapifolia* differs from Sternberg's form, and is classed with *S. hæringiana*.

No idea can be formed from our specimens about the character of the rhachis, though all the other characters agree with those of *Sabal major*, Heer.

We have, however, some other fragments of palm leaves amongst the fossils from the Kasauli beds. Amongst them is especially one good specimen (fig. 3) which though of a very small size, yet exhibits a portion of the stalk and also the rhachis. The stalk widens somewhat at the upper end, whence the rhachis originates as a long pointed process, on both sides of which the leaf plaits are inserted, which are distinctly keeled. It belongs most probably to a very young plant, considering its small size; but if we compare it with the various figures of fossil palm leaves, it again agrees best with *Sabal major*, Heer, especially with

[1] The locality is Chakoti, Jhelum valley, above Murree.
[2] Flora tert. Helvetiæ, Vol. I, 1855, p. 88, Tabs. XXXV, XXXVI, fig. 12.
[3] Denkschriften d. Kais. Akad. d. Wiss. in Wien, Vol. XXVI, 1867, p. 108, Pl. VIII, IX.
[4] 1847, p. 42, Pl. XIV, fig. 2.
[5] Abhdl. d. k. k. Geol. Reichsaustalt, Vol. II, p. 38, Tab. III, figs. 3-7.
[6] Fl. d. Vorw. 1, 2. p. 32, Pl. XXI.

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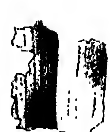

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some of those specimens figured by Ettingshausen in his fossil Flora of Hæring, Tyrol (*l. c.*), but best with the restored figure of *Sabal major*, given by Heer in his tertiary flora of Switzerland (*l. c.*), pl. XLI, fig. 7. This view is further confirmed by the circumstance that, together with this specimen, there were found fragments of the plaits of a larger leaf (figs. 4, 5), very nearly approaching in size the first described specimen brought by Mr. Lydekker from the Murree beds and classed by me with *Sabal major*. The presumption is only natural that these latter fragments belong to leaves of the same plant as the specimen just described from the Kasauli beds. Dr. Kane (*l. c.*) referred these specimens to *Flabellaria rapifolia*, Sternberg, which, as we have seen, is a synonym for *Sabal major*, Heer.

This identification of the palm leaves from the two localities is also fairly in accordance with the geological horizon of the strata at the said localities (Murree beds north of Murree and Kasauli beds near Kasauli); and even if there were a slight difference in age of the respective beds, in which this species occurs here, in India, yet its occurrence in both would find sufficient explanation in an analogous distribution of *Sabal major* in extra-Indian tertiary beds. It is known from many localities in the European tertiaries, *i.e.*, of Austria, Germany, Italy, France, and England; and as to the horizon, it begins in the tongrian stage (lowest miocene) and lasts till middle miocene.

In the botanical system, *Sabal* is classed with the *Coryphinæ*, subtribe *Sabalineæ*, to which belong amongst others the genera *Corypha* (*C. umbraculifera*—the Talipot of Ceylon, and two other species of Bengal) and *Chamærops* (one species of which lives in the Punjab).

Sabal itself is a North-American genus in the living flora.

EXPLANATION OF PLATE.

Figs. 1 and 2. Portions of a palm leaf, referable to *Sabal major*, Heer, from the Murree beds at Chakoti, Jhelam valley, above Murree.

Fig. 3. A portion of a small palm leaf, exhibiting part of the stalk and the rhachis, agreeing in all its characters with *Sabal major*, Heer. From the Kasauli beds at Kasauli.

Figs. 4 and 5. Fragments of plaits of a palm leaf occurring with the preceding (fig. 3) at the same locality and belonging apparently to the same species.

On Iridosmine *from the* Noa-Dihing River, Upper Assam, *and on* Platinum *from* Chutia Nágpur, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

Assam.

In 1855 Captain E. T. Dalton and Lieutenant-Colonel S. F. Hannay, who had previously been engaged in researches on the mode of occurrence of gold in Upper Assam, were deputed by Government to undertake a further examination of the auriferous deposits there. A summary of their report, which was submitted in October of that year, is published in the Memoirs of the Geological Survey, Vol. I, p. 90.

Amongst other rivers examined was the Noa-Dihing, the sand of which was found to contain platinum as well as gold.

The samples of gold obtained by the above-mentioned officers were eventually deposited in the Geological Museum, and having recently had occasion to examine them with some care, I detected in that from the Noa-Dihing, besides the platinum already mentioned, iridosmine also.

Of the entire sample (weighing about 75 grains) the great bulk, probably over 90 per cent., is gold in scales or flattened grains. The remainder consists of quartz and other silicious grains, including a few red ones like garnet and some black which are probably schorl, with magnetic iron; and besides small and minute flattened grains of platinum, a not inconsiderable proportion of lead-grey scales with metallic lustre. They are of high specific gravity, as is shown by the ease with which they can be separated by a fine jet of water from most of the other non-auriferous matter, and are hard enough to scratch glass. They are insoluble in aqua regia, and infusible before the blowpipe, but lose their lustre when heated. Fused with nitre in a platinum spoon they give the odour of osmic acid, and, mixed with the violet potassium flame, a yellow streaky luminous one. Their dark colour, and their loss of lustre before the blowpipe, point to their being sisserskite, the variety of iridosmine containing a high percentage of osmium in comparison to that of iridium. The largest scale of iridosmine weighs ·06 grains, the largest of platinum weighing ·095.

It will be seen that the proportion these metals bear to the gold in the sample under discussion is comparatively trifling. But it is possible that if they were specially looked for in the Dihing river they might be found in greater abundance. It appears that in Burmah, where also platinum is found in conjunction with gold, it is the latter only on which much value is placed. "Mixed "with the gold dust, found to the northward of Ava, are a quantity of grains of "metal having every appearance of iron [1] * * * . The Burmese "look chiefly for the gold dust, separating and bringing that alone generally to "Ava"[2] It is not impossible that the gold washers employed by Captain Dalton in ignorance of the value of the platinum and iridosmine, may have treated them in the same way as the Burmese, and picked out by hand any grains sufficiently large to attract the eye.

With reference to the origin of the platinum and iridosmine, it can scarcely be doubted that they are derived from some of the crystalline rocks which are known to form a portion at least of the mountainous mass towards the head of the Dihing river. In the not very numerous cases in which platinum has been traced to its parent rock in other parts of the world, it appears to have been found in most instances either in auriferous quartz veins traversing crystalline rocks, or

[1] The platinum. Asiatic Researches, Vol. XVIII, pt. II, pp. 280, 281. Jour. As. Soc., Bengal Vol. I, p. 17.

[2] In the Indus Valley also, where, according to Mr. Baden Powell, platinum is found in smal quantity with gold, the former is said to be rejected as useless. (Economic Products of the Punjab Vol. I, p. 14.)

(accompanied frequently by chromite), in serpentine. As serpentine is known to exist largely in the hills to the east of Assam,[1] and in Upper Burmah also, it might perhaps be suspected to be the platiniferous matrix in those provinces. But the intimate association of the platinum with gold in both countries (coupled, it might perhaps be added, with the fact that chromite has never been observed in the Assam or Burmese auriferous sands) points rather to the rocks in which gold is usually found as those from which the platinum has been derived.

Chutia Nágpur.

We are indebted to Messrs. Schoene, Kilburn and Co. for a sample of stream gold from the Garam River, near Dhadka, Mánbhum, lately presented to the Museum. The specimen weighs about 57 grains, and includes four comparatively large pieces of gold, aggregating 26·5 grains, of which the heaviest weighs 9·0 grains. The remainder is gold in much smaller scales and fine dust, with a little black iron sand (chiefly ilmenite, with some magnetite) and a few minute grains and scales of a steel-grey colour. These are malleable; infusible before the blowpipe; insoluble in hydrochloric or nitric acid, but soluble in aqua regia. The solution when evaporated to dryness, mixed with water and a drop of a dilute solution of ammonium chloride, and allowed to evaporate over oil of vitriol, deposits minute yellow crystals of apparently octahedral form. The scales are evidently platinum. They occur in extremely small quantity however, the platinum being only 'a trace' in comparison to the gold. The largest scale in the whole sample weighed only ·005 grains.

On subsequently examining other samples of Indian stream gold in the Museum, I found similar, but still smaller, scales, which behaved in the same way with reagents, &c., in gold from Lándu, Chaibássa. Scales of the same appearance were also observed in a specimen of gold from Mánbhum, the exact locality of which is not given, and in another from the Bráhmini River, Tributary Mehals, Orissa. There can scarcely be much doubt that these are platinum also, but they were not examined with reagents, the scales from the Bráhmini being indeed almost too minute to admit of such treatment.

It seems therefore not improbable that platinum is somewhat widely diffused in the southern part of Chutia Nágpur, &c., and perhaps throughout a larger area. But the specimens alluded to do not in themselves give ground for believing that it occurs in more than minute quantity. It is, however, possible that the gold washers may sometimes find grains sufficiently large to attract their attention, and that they reject them as useless.

[1] Mr. H. B. Medlicott informs me that quantities of serpentinous boulders are washed down to the plains by the Dihing and Brahmaputra (Brahmakund) rivers. Captain Hannay found similar rolled fragments in the Digáru, and there is in the Museum a rolled pebble of the same rock from the Dihing.

On (1) *a* Copper Mine *lately opened near* Yongri Hill, *in the* Dárjiling District; (2) Arsenical Pyrites *in the same neighbourhood;* (3) Kaolin *at* Dárjiling; *being 3rd Appendix to a Report "on the Geology and Mineral resources of the Dárjiling District and the Western Duárs;*[1]*" by* F. R. MALLET, *Geological Survey of India.*

Yongri copper mine.

During the present year a new copper mine has been opened on the western flank of Yongri hill, in the Kálimpung sub-division of the Dárjiling district. The Government of Bengal having requested that an officer of the Geological Survey should be sent to report on it, and the duty having been assigned to me, I proceeded to the locality at the end of October.

For a general account of copper mining and smelting in the Dárjiling hills, I would refer to my report on the mineral resources of the district, published in the memoirs of the Geological Survey, Vol. XI, p. 69. The present note refers to the Yongri neighbourhood alone.

The new mine is situated on the left side of a small *jhora* (stream), about three-quarters of a mile west of Yongri Hill (N. lat. 26° 57′, E. long. 88° 31′), at an elevation of about 2,500 feet above the sea. The rock in which the metalliferous band occurs is gray clay slate, of the ordinary type in the Dáling series, which is rather broken and contorted, but which has an average dip at the mine of 60°—80° to S. 30 W. I obtained no clear evidence of there being more than one metalliferous seam. This was first worked by an adit driven in from the hill-side at the spot where the ore originally revealed itself by its rusty, gossan-like, appearance at the surface, and subsequently by two other adits within a few yards of the first one, and by galleries sunk from the above along the dip of the beds. The principal gallery having been sunk to a depth at which the influx of water was too great to allow of its being profitably carried further, an adit was driven in, across the strike of the rocks, somewhat lower down the hill-side, which cut the cupriferous seam about 100 feet from the entrance. The miners then worked upwards towards the old workings, and at the time of my visit were working downwards along the dip of the seam. The driving of this adit through 100 feet of unproductive rock, in order to reach the cupriferous bed, showed a knowledge of the principles of mining, and an enterprise, of which I have not seen any equal example in the Sikkim mines, unless perhaps in that at Rattu.[2] The cupriferous seam at the spot where the miners were working at the time of my visit was about 7 or 8 inches thick, consisting of irregular quartzose layers (interbanded with some clay-slate) through which the ore is disseminated. The latter is copper pyrites, with a large proportion of mundic (iron pyrites), and accompanied by some ochreous oxide of iron and a little black copper as results of alteration.

It will be remarked, therefore, that the Yongri seam, like all the other known cupriferous seams in the Dárjiling District,[3] (1*stly*) occurs in the rocks of the

[1] Memoirs Geol. Surv. Ind., Vol. XI, Pt. I. The second appendix is contained in Vol. X of the Records, p. 143.

[2] Memoirs, Geol. Surv. Ind., Vol. XI, p. 75.

[3] Memoirs Geol. Surv. Ind., Vol. XI, p. 72.

Dáling series; (2ndly) is a bed, not a true lode; and (3rdly) that the ore is copper pyrites.

As is commonly the case in the Dárjiling mines, the seam is not of constant thickness, expanding in some places, as I was informed by the miners, to a foot or so, and in others thinning to only 1 or 2 inches. A sample of the ore, as it was being brought out from the mine, yielded on assay 1·5 per cent. of copper, while a sample of picked ore gave 6·6 per cent.

On the whole I should be inclined to consider the Yongri cupriferous seam as scarcely on a par with that at Mangphu[1] on the Tísta, and certainly not equal to that at Rattu[2] in Sikkim. The band is not very thick; there is a large amount of mundic in the ore, and the assays show a rather low percentage of copper. Of course this opinion is founded on the state of the different mines *at the times I visited them* respectively, but the productiveness of the same seam varies considerably, owing to fluctuations, both in its thickness, and in the proportion of ore contained in the gangue.

One hundred and fifty or 200 yards S. 30 E. of the above mine, a trial drift was carried in some distance, at a spot where the usual gossany indications were observed. It did not turn out well, however, and is now abandoned and filled with water.

Taking the general strike of the rocks into account, it is not impossible perhaps not improbable, that the Yongri cupriferous band is on the same horizon as the metalliferous strata at Mangphu. The chance is at least sufficiently great to suggest a somewhat promising clue towards the discovery of new outcrops, between the two positions, to any one with sufficient geological knowledge to apprehend the bearing of the facts, but such knowledge is unfortunately not possessed by the native miners.

Smelting was being carried on at the Yongri mine when I was there. As the methods of dressing the ore, and subsequent reduction, are, however, quite similar to those I have already described at some length,[3] it would be useless to enter into the details here. The copper was being sold at Rs. 2-8 per three sers, a portion of it being worked up into cooking vessels, &c., at Surung, a village in the neighbourhood.

Arsenical pyrites at Sampthar Hill.

On the western flank of Sampthar Hill, about half a mile W. 20° S. from the highest summit, and a mile and a half north-east from the Yongri mine, at an elevation of about 4,000 feet, the outcrop of a metalliferous band dipping north-east at 50° is exposed for five or six yards. The seam is about a foot thick, of which perhaps two-thirds is ore, the remainder being rusty quartzose schist, which divides the band into two layers, of which the upper is much thicker than the lower. Both consist almost entirely of ore, with but little gangue intermixed. Beneath the metalliferous seam a foot or so of rusty quartz schist is visible. No other rock is exposed close by, but a little lower down the hill the ordinary gray clay-slate of the Dáling series is seen. The ore is arsenical pyrites, with a somewhat considerable proportion of mundic, and a little copper pyrites.

As white arsenic and orpiment (arsenious acid and arsenious sulphide)

[1] Memoirs Geol. Surv. Ind., Vol. XI, p. 76. [2] *Ibid.*, p. 75. [3] *Ibid.*, p. 69.

are both easily prepared from arsenical pyrites, and orpiment is used to a considerable extent in India in connection with the preparation of hides, it seems likely that if some of the copper miners were to learn the way of making the above-mentioned products, they could profitably work the Sampthar ore, especially as some copper could be subsequently extracted from the spent pyrites. Whether Government would consider it advisable to allow the manufacture of arsenical compounds is of course a separate question.

Kaolin at Dárjiling.

The site of the intended European hospital at Dárjiling is on a small hillock, the apex of which has been removed, and the earth, &c., thrown to the sides to form the requisite level space. The stuff cut through is clay and partially decomposed gneiss, the latter of which includes a bed, about 6 feet thick, of a white rock composed of quartz and decomposed felspar verging towards kaolin. The stone is soft when first extracted, and easily broken between the fingers. It bears a close resemblance in appearance to the decomposed granite, found in Cornwall, from which 'China clay' is so largely prepared, by elutriation, for use in the English manufactories of porcelain and the finer kinds of pottery. 'Cornish stone' is a similar material in a less decomposed state. The Dárjiling rock could undoubtedly be used in the manufacture of ceramic ware, but a trial would be needed to ascertain whether it is sufficiently pure for porcelain-making. Tested on a small scale, it was found to fuse *per se* at a white heat into a translucent white, or grayish-white, enamel. There are dark spots scattered through it here and there, due to more or less completely decomposed garnets. These, however, could be picked out by hand to some extent if the rock were used raw. If washed for kaolin, such impurities would of course be removed during the elutriation. A considerable quantity of the stone has been quarried in lowering the hospital site, but no further supply can be obtained there after the building has been commenced. Similar stuff, however, is probably to be obtained elsewhere from the gneissose rocks of the Dárjiling hills, and may perhaps be found capable of local utilisation.

Analyses *of* Coal *and* Fire-clay *from the* Makum *Coal-field*, Upper Assam.

We are indebted to Messrs. Shaw, Finlayson and Co. for permission to publish the following analyses, which have been lately made, of coals from the Makum field:—

From RICHARD SMITH, ESQ., *Metallurgical Laboratory, Royal School of Mines, London, to the Assam Railway and Trading Company, London,—dated 12th September 1881.*

The ten samples of coals from the "Makum Coal Fields," Assam, marked Nos. 1, 1*a*, 2, 2*a*, 3, 4, 5, 6, 7 and 8 respectively, and one sample of clay, have been submitted to examination according to the instructions of your Secretary, Mr. W. Tudor Johns.

PHYSICAL CHARACTERS.—The various coals do not differ much in external appearance; they are brownish-black or black, hard, bright, do not soil the fingers when touched; the fracture is uneven, and some of the samples have flat, somewhat conchoidal patches; the fragments or lumps are more or less cubical, or have irregular bedding cleavage, and some of them exhibit a peculiar form, resembling an imperfectly columnar structure.

CHEMICAL COMPOSITION.—In the following *Table A* are the analyses of the coals, made on the samples as received, and inclusive of the water present :—

TABLE A.

	1	1a	2	2a	3	4	5	6	7	8
Carbon . .	74·63	76·81	75·90	76·36	75·40	74·54	78·00	77·90	74·66	74·81
Hydrogen .	5·03	5·17	5·22	5·31	5·22	5·13	5·27	5·30	5·17	4·95
Oxygen . . } Nitrogen . . }	14·25	12·88	11·85	11·12	11·50	11·67	12·18	11·75	14·49	12·66
Sulphur . .	1·38	1·03	1·73	2·71	2·56	2·81	1·40	2·30	2·88	3·40
Ash (red) .	2·66	1·66	3·00	2·00	3·00	3·50	1·00	1·10	1·00	2·33
Water . . (hygroscopic)	2·05	2·45	2·30	2·50	2·20	2·15	2·15	1·65	1·80	2·15
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

The following *Table B* represents the composition of the coals calculated on 100 parts, and exclusive of sulphur, water and ash, and are added for comparison. There is a marked similarity between them, but Nos. 1 and 7 contain less carbon and more oxygen and nitrogen :—

TABLE B.

Carbon. . .	79·47	80·97	81·64	82·08	81·83	81·43	81·72	82·05	79·15	81·21
Hydrogen . .	5·35	5·45	5·61	5·72	5·66	5·61	5·41	5·58	5·48	5·37
Oxygen . . } Nitrogen . . }	15·18	13·58	12·75	12·20	12·51	12·96	12·87	12·37	15·37	13·42
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

The nitrogen is generally present in coals to the extent of 1 to 2 per cent. It was not separately determined, as it was not considered necessary.

The sulphur is present in the coals partly in organic combination (with carbon) and partly in combination with iron as iron pyrites, and probably to some extent as sulphate of protoxide or peroxide of iron, resulting from weathering action upon the pyrites. Patches of iron pyrites (a pale brass-coloured mineral) were observed in two of the coals.

The ash present in the coals is small in quantity, averaging 2·03 per cent. This is an advantage, as the proportion of "clinker" produced during burning would be relatively smaller than produced from many varieties of coals. Compared with other varieties of Indian coals which have been examined, the ash is considerably less.

When a portion of each of the coarsely powdered coals respectively is heated in a closed vessel, the gases given off burn with a yellow smokey flame, and the residual coke is coherent, firm, somewhat dull, more or less porous, and increased in bulk. No marked difference was observed in the character of the gases evolved, or of the residual cokes produced from any of the coals.

The percentage results obtained are given in *Table C*:—

TABLE C.

Coke . . .	56·50	59·00	58·25	58·50	57·40	56·40	58·10	56·85	57·20	56·50
Volatile Gases .	41·45	38·55	39·45	39·00	40·30	41·45	39·75	41·50	41·00	41·35
Water . . .	2·05	2·45	2·30	2·50	2·30	2·15	2·15	1·65	1·80	2·15
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·0

The gases given off from the various samples of coals during the coking experiments are highly illuminating; they may, therefore, be applied for purposes of gas-making.

As the samples submitted to examination have been taken from the "outcrop" or surface ground, the coals may probably be found to improve in charactor and have a less proportion of sulphur and ash when worked lower down.

In our experimental trial, the lumps of coal, when first heated, do not appear to soften or stick together to any extent, afterwards they burn freely, and the "fire" remains open, which is favourable as regards coals required for steam purposes.

The coal burns well, but would at first give off a quantity of smoke while putting on fresh fuel. This could be avoided to a certain extent by pushing back the ignited fuel and feeding in the fresh coal at the front of the furnace. It would also be advisable at first to admit a good supply of air to burn the gases produced in the furnace and prevent loss of heat by their escape unburnt up the funnel. The supply of air would afterwards require to be regulated in order to prevent a too rapid combustion of the coke. If local and other circumstances permit, an advantage might be gained by admixture of the coal with a certain proportion of Anthracite or other smokeless coal.

In conclusion, I am of opinion that the coals may be regarded as valuable fuel for various purposes. As steam coals, and also for gas-making, coking or manufacturing and household use, I also think that they may compete successfully with many British coals.

CLAY.—The sample was more or less laminated or shaly in character. It was tested, and found to be a "fire-clay," containing some iron pyrites and coaly matter. Fire-clays often occur in association with coal. When the crude clay is exposed to the highest temperature attainable in an air furnace (sufficient to melt wrought iron), the external surface becomes glazed, and it exhibits other indications of softening to a certain extent. The fire-clay might probably be used for some purposes to which clays of a refractory character are applied, but it would not be of best quality or stand exposure to a long continuous heat. If the clay is previously submitted to a "washing" process to separate the iron pyrites and coaly matter, it may probably diminish its liability to softening when exposed to high temperatures. As this sample was from the "out-crop" or surface ground, it may be possible that clay of improved quality may be found when the working of the coal is more developed.

(*Signed*) RICHARD SMITH.

Analysis of "Assam" Coal (Makum Field), by the Gas Light, and Coke Company.

Gas, per ton	10,900 Cubic Feet.
Illuminating power	17·2 Sperm Candles.
Coke	11 Cwt. to the Ton.
Volatile Matter	46·5 per cent.
Ash in Coal	2·0 per cent.
Ash in Coke	4·3 per cent.

NOTE.—The coal contains a small percentage of ash, and produces a coke of very fair quality, lthough not quite equal to that from Newcastle Coal, yet would be readily saleable.

LONDON, August 27th, 1881. (*Signed*) ALFRED KITT.

The above analyses, coupled with those given in Vol. X, p. 156, furnish data for comparing the Makum coals with those from the Ráníganj field. The comparison is of especial value, as it is against the Ráníganj coal that that of Assam has to compete at present for use on the Upper Brahmaputra. And the fuel from the two sources will doubtless be brought into much greater competition on the railways of North-Eastern Bengal, when the completion of the line, now being constructed from the Makum field to the river at Dibrugarh, shall have rendered the systematic working of the Assam coal practicable.

Taking the mean of the ten analyses given of Makum coals, and comparing it with the average composition of 31 Ráníganj coals, as determined by Mr. Tween, we have—

	Mean composition of 10 Makum coals.	Mean composition of 31 Ráníganj coals.
Carbon	75·90	66·20
Hydrogen	5·18	4·64
Oxygen and Nitrogen	12·42	11·30
Sulphur	2·32	·85
Ash	2·03	17·01
Hygroscopic water	2·15	[1]
	100·00	100·00

It is scarcely necessary to remark that the heating power of coal depends on the high percentage of carbon and (available) hydrogen it contains, and on the low percentage of the remaining constituents. It will be seen, then, that the Makum compares most favourably with the Ráníganj, containing as it does 10 per cent. more carbon, about the same amounts of hydrogen, and of oxygen plus nitrogen, and less than one-eighth the quantity of ash.

[1] The hygroscopic water contained in the Ráníganj coals is not separately given. They were possibly dried before analysis. The average amount of water found in the same coals during their proximate analysis was 4·8 per cent.

If the highest and lowest percentages of the different constituents be compared, the result is equally favourable to the Assam coal.

	Highest percentage amongst 10 Makum coals.	Highest percentage amongst 31 Ránigani coals.	Lowest percentage amongst 10 Makum coals.	Lowest percentage amongst 31 Ránigani coals.
Carbon	78·00	73·39	74·54	57·09
Hydrogen	5·31	5·06	4·95	3·46
Oxygen and Nitrogen ...	14·49	14·27	11·12	4·35
Sulphur	3·81	1·63	1·03	·37
Ash	3·00	25·80	1·00	13·00

The following figures, giving the mean proximate composition of the coals from each locality, enable a comparison to be made of a somewhat different kind.—

	Mean composition of 28 Assam coals.[1]	Mean composition of 31 Ránigani coals.[2]
Fixed carbon	56·5	53·20
Volatile matter (exclusive of water)	34·6	25·83
Hygroscopic water	5·0	4·80
Ash	3·9	16·17
	100·0	100·00

or, exclusive of water—

	Mean composition of 27 Assam coals.	Mean composition of 31 Ránigani coals.
Fixed carbon	60·0	55·88
Volatile matter	36·2	27·13
Ash	3·8	16·99
	100·0	100·00

Taking the nitrogen at 1·5 per cent., and calculating the theoretic calorific power in centigrade heat units, we have—

	Mean calorific power.
31 Ránigani coals	6526
10 Makum coals	7447

or as 7 to 8. It appears from Mr. Hughes' remarks[3] that the calorific power of none of the 31 samples of Ránigani coal exceeded 7040.

The one point in which the analyses show an inferiority in the Makum coals is in the proportion of sulphur they contain. This is without doubt a somewhat serious defect. Most of the Assam, however, cannot be considered a "brassy" coal. There are at present in the Geological Museum specimens from twelve different localities in the Makum, Názira, and Jángi fields, which were collected in 1874, 1875, and 1876. The majority contain no pyrites visible to the eye, and,

[1] Memoirs Geol. Surv. India, Vol. XII, p. 349. [2] Records Geol. Surv. India, Vol. X, p. 156.
[3] *Ibid.*, p. 158.

after six or eight years' exposure to the heat and damp of Calcutta, seven do not show even incipient signs of alteration, while the other five are more or less disintegrated through the oxidation of the pyrites contained in them. It remains to be seen, therefore, whether by proper care the more and less sulphureous coals cannot be worked separately, and used for different purposes.[1]

With reference to gas manufacture, Mr. Hughes has stated[2] that the best known gas coal in the Ráníganj field is that from Sánktoria, which yields about 9,000 cubic feet per ton. Mr. Kitt's analysis gave 10,900 feet from that of Makum. In this connection it will be observed, on comparison of the ultimate and proximate analyses of Makum and Ráníganj coals given above, that a large proportion of the excess of carbon in the former is contained in the volatile portion of the fuel.

F. R. MALLET.

Experiments on the Coal *of* Pind Dadun Khán, Salt-range, *with reference to the production of* Gas; *made April 29th*, 1881, *by* MR. C. H. BLACKBURN, *Superintendent of the Ráwalpindi Gas-works.*

There is reason to believe that the sample of coal on which the experiments were made was a picked one, and that it is improbable that similar results would be obtained from an average sample of the general bulk.

The coal was rather small, having been much broken up in transit by rail. On the whole it was very dull and heavy, but there were a few "shiny" pieces here and there. At 12 noon, the three retorts were charged, each with one maund:—

Time.	State of Meter.	Gas made.	Total Production.
		C. ft.	C. ft.
12 noon	9,342,100	...	...
12-30 P. M.	9,342,540	440	...
1 "	9,342,780	240	680
1-30 "	9,342,960	180	860
2 "	9,343,100	140	1,000
2-30 "	9,343,190	90	1,090
3-00 "	9,343,250	60	1,150
3-30 "	9,343,270	20	1,170
4 "	9,343,290	20	1,190
4-30 "	9,343,300	10	1,200
5 "	9,343,300	*Nil*	1,200
5-10 "	Retorts drawn.		

3 mds. produced 1,200 c. ft. = 400 c. ft. per maund.

400 × 27¼ = 10,900 c. ft. per ton.

The coke produced is very small indeed—like fine ash, and smells excessively of sulphur.

Total produce of coke = mds. 1-34.'.

3 mds. coal produced 74 seers coke = seers 24⅔ per maund.

∴ 24⅔ × 27¼ = mds. 16-29 of coke per ton of coal.

The gas was roughly tested photometrically the same evening; the burner used was London D., and the light given was very good.

The result of the testing showed the gas to be equal to about 12½ standard candles.

The amount of sulphur however is excessive, as shown by the test papers hereto attached, and which were exposed only during the period of testing; and the smell in the close Photometer house was very pungent.

[1] Memoirs, XII, 349. [2] Vol. X, p. 15

Report on the proceedings and results of the International Geological Congress *of* Bologna. BY W. T. BLANFORD, F.R.S., *Senior Deputy Superintendent, Geological Survey of India.*

The origin of the Bologna Geological Congress may be stated in very few words. A number of geologists of various nations, after visiting the Universal Exhibition of Philadelphia in 1876, met at Buffalo and nominated a Committee to make the necessary preliminary arrangements for an International Geological Congress at Paris in 1878. The object of this Congress was to decide upon rules for the construction of geological maps, and for geological nomenclature and classification.

The Geological Congress of Paris, the first of a series that may very possibly be further extended, met on the 29th of August 1878 at the Trocadero Palace, and, having elected M. Hébert President, proceeded to a discussion, which lasted for seven days, on the various subjects included in the general-programme. Little more was done than to determine upon the course to be adopted in future, to nominate two International Committees who should report upon the two important questions of (1) geological nomenclature, and (2) the colours, signs, and other marks to be used in geological maps, to entrust a third Committee with the task of reporting upon the rules of nomenclature to be used in palæontology, and to determine that the second meeting of the Congress should take place at Bologna in Italy in the present year 1881. A fresh Committee was appointed to make arrangements for the Bologna Meeting or Second International Geological Congress, which met on the 26th September last.

The Committee on geological nomenclature (*commission pour l'unification de la nomenclature en géologie*), with the addition of representatives of some nations not included in the original list, finally comprised the following:—

Professor F. RÖMER	Germany
Prof. JAS. HALL	United States of America.
Dr. STERRY HUNT	Canada.
Professor A. LIVERSIDGE	Australia.
Dr. M. E. MOJSISOVICS	Austria.
Professor G. DEWALQUE	Belgium.
Prof. HÉBERT	France.
Prof. J. VILANOVA	Spain.
Mr. C. RIBEIRO	Portugal.
Professor T. McK. HUGHES	British Isles.
Prof. J. SZABO	Hungary.
Prof. J. CAPELLINI	Italy.
Prof. STEPHANESCO	Roumania
Prof. INOSTRANZEFF	Russia.
Prof. LUNDGREN	Scandinavia.
Prof. A. FAVRE	Switzerland.

The members mentioned, with very few exceptions, formed a national Sub-Committee, exclusively composed of geologists of his own nationality. Of these different Sub-Committees, 7, *viz.*, those for Belgium, France, Spain and Portugal (jointly), Great Britain and Ireland, Hungary, Italy, and Switzerland, reported more or less fully to the general Committee. No reports were received from the other Sub-Committees, but a separate communication was sent by Prof. J. D. Dana of the United States, and this was printed with the others in the general report drawn up by Prof. Dewalque, and furnished to each member of the Bologna Congress.

The Committee on colours and signs for geological maps (*unification des figurés ou des procédés graphiques en géologie*) consisted of the following members, the majority of whom, as in the case of the Committee on nomenclature formed Sub-Committees of their own countrymen:—

A. Selwyn, Director of the Geological Survey of Canada, for Canada.

J. P. Lesley, Director of the Geological Survey of Pensylvania—United States.

A. Liversidge, Professor at the University of Sidney—Australia.

A. Ramsay, Director of the Geological Survey of Great Britain and Ireland—British Isles.

Otto Torell, Director of the Geological maps of Sweden—Scandinavia.

V. von Moeller, Professor at the Institute of Mines, St. Petersburgh—Russia

M. v. Hantken, Director of the Geological Institute at Buda-Pesth—Hungary.

Freiherr v. Hauer, Director of the Imperial and Royal Geological Reichsanstalt at Vienna—Austria.

G. W. Gümbel, Director of the Geological map of Bavaria—Germany.

F. Giordano, Inspector-General of Mines at Rome—Italy.

J. B. de Chancourtois, Professor at the School of Mines in Paris—France.

E. Dupont, Director of the Royal Belgian Museum at Brussels—Belgium.

C. Ribeiro, Chief of the Geological Section of Portugal at Lisbon—Iberian Peninsula.

E. Renevier, Professor at the Academy of Lausanne—Switzerland.

Mr. Selwyn was President and M. Renevier Secretary, and the latter drew up the report of the general Committee. He had previously published two memoirs with résumés of the Sub-Committee's reports. The first and most important question was the adoption of an international scale of colours to represent the geological series, each colour in the scale corresponding to one of the great sub-divisions, such as Carboniferous or Jurassic, under which, by the common consent of geologists, sedimentary rocks have been classified. The other questions considered were (2) the colouration to be adopted for igneous rocks; (3) the lettering to be employed for the distinction of beds of different geological ages; (4) various signs and marks for the representation of petrological, palæontological and other characters; (5) the scale for general maps; and (6) the organisation of future work.

There can be no doubt that for all the geological surveys of the world, and perhaps for geologists in general, the questions affecting geological colours and signs were the most important of all those submitted to the Congress. They had the enormous advantage of being entirely independent of language,—a difficulty which must always interfere with the adoption of a general nomenclature, for terms in one language are far from being exactly equivalent to corresponding terms of the same etymological derivation in another tongue. But, unfortunately, so many widely-diverging systems of colouration have been adopted by geologists in various countries, that any general compromise must produce a difference between maps coloured on the scale adopted, and all those previously issued. And, as will be seen in the sequel, although the Congress came to a decision on several points, a far larger number were left undecided.

The importance and difficulty of the question of map colouration and signs induced the committee of organisation to offer a reward of five thousand Francs (£200) for the best memoir on the subject. Several memoirs[1] were received, but none, in the opinion of the judges, merited the full prize, which was distributed amongst the three best dissertations.[2]

The third committee, on the nomenclature of species, consisted of MM. Cotteau, Douvillé, Gaudry, Gosselet, Pomel, and De Saporta for Palæontology, and M.M. Des Cloizeaux and Jannettaz for Mineralogy. The palæontological committee, of which Mr. Gaudry was President and Mr. Douvillé Secretary, furnished a report; but this report has not the same importance as the others already mentioned; for, despite the high position occupied by several of the members, the circumstance of all belonging to one nation deprives the Committee of the representative character possessed by the other two; and with regard to palæontological nomenclature, there can be no doubt that the rules to be adopted for all biology, both of living and fossil forms, must be determined by a general consensus of botanists and zoologists,—palæontologists being admitted as biologists and not as geologists. It is manifest that for a geological congress to attempt to settle rules for biological nomenclature would be as ineffectual as for a congress of biologists to attempt to define geological terms. However excellent the rules adopted might be, they would not receive general acceptance, because the legislators would not be considered competent to decide on matters with which many of them could have but an imperfect acquaintance.

Indeed, it may here be stated, once for all, that although a geological congress, as at present constituted, has great advantages for the discussion of various questions proposed to it, it also suffers from great disadvantages in endeavouring to decide upon difficult points. The majority of the members necessarily belong to the nation in whose country the meeting is held, and although all are qualified who have the right to vote (none being admitted as effective members who are not either geologists by profession or else the authors of geological memoirs), still there is sometimes a preponderance of particular views amongst geologists of one nation, which may not be as generally held by those in other countries. For some of the very delicate and difficult points involved in questions like that of nomenclature, it would be far more satisfactory, if practicable, that the voting on disputed questions should be limited to the representatives of geological societies and geological surveys.

The difficulties of language appear more formidable than they have been found in reality to be. The sole language employed at the Paris and Bologna

[1] Six I believe, but I am not quite sure of the number.

[2] These were by MM. Heim of Zurich, Carpinski of St. Petersburg, and Maillard of Lausanne

Congresses was French, and almost necessarily so, since it is the only one that is easily understood by nearly all the members. A slight advantage was doubtless afforded to the French and Belgian, and to some of the Swiss, members, who used their native tongue, but all, however imperfect their powers of expressing themselves, were heard with equal patience; and it is not quite certain that the abridgement of the discussions, owing to the imperfect power of many speakers to express themselves with fluency, was not a gain that counterbalanced many disadvantages.

As already mentioned, the second Geological Congress, which I attended by order of the Government of India, met at Bologna on the 26th September 1881. Altogether about 200 members were present, of whom 130 were Italians and 70 foreigners. Professor Capellini was elected President, and the following were made Vice-Presidents, as representatives of the different countries named:

Austria	M. Mojsisovics.
Bavaria	„ Zittel.
Belgium	„ Dewalque.
Canada	„ Sterry Hunt.
Denmark	„ Waldmar-Schmidt.
Spain	„ Vilanova.
United States	„ J. Hall.
France	„ Daubrée.
Great Britain	„ McK. Hughes.
Hungary	„ Szabo.
India	„ Blanford.
Italy	„ Meneghini.
„	„ De Zigno.
Portugal	„ Delgado.
Prussia	„ Beyrich.
Roumania	„ Stefanesco.
Russia	„ v. Moeller.
Sweden	„ Torell.
Switzerland	„ Renevier.

M. Giordano was elected General Secretary; Messrs. Bornemann, Delaire, Fontannes, Pilar, Taramelli, Topley, Uzielli, and Zezi, Secretaries; and M. Scarabelli, Treasurer. M. Hébert, the President of the first Congress, attended the second Congress throughout, and M. Q. Sella was Honorary President.

The above names are merely given to show that the Congress was fairly representative. The greater number are well-known geologists, and amongst the other members of Congress were several distinguished men. All those named, with the addition of Messrs. Bioche, Bosniaski, Briart, De Chancourtois, Cocchi, Cossa, Fischer, Gemmellaro, Guiscardi, De Hantken, Hauchecorne, Issel, Inostranzeff, Jaccard, Malaise, Mayer-Eymar, Omboni, Pellati, Pirona, Schmidt, Seguenza, Silvestri, Stoppani, and Trautschold, formed the Council or General Committee of the Congress.

The first meeting, that of September 26th, was chiefly formal, and devoted to the election of officers and delivery of addresses. The meetings of September 27th and 28th were devoted to geological nomenclature, those of the 29th and 30th to geological maps (*unification des figurés*), that of October 1st to palæontological nomenclature, and on October 2nd the Congress was formally closed and Berlin chosen as the seat of the next meeting in 1884. The following account of the results of the Congress will show what has been done. The principal of them are contained in the "*Procès-verbaux Sommaires*" already printed, giving short accounts of the business transacted each day.

In the sittings of September 27th the following resolutions were adopted by a large majority. They were taken from the report of the French Committee on nomenclature:—

Geology *is the history of the earth.*[1] *The facts which enable us to retrace* (restaurer) *this history are contained in the* mineral masses *constituting the crust of the earth.*

Mineral masses.—*Mineral masses may be considered under three aspects; that of their nature, or of their composition, that of their origin, and that of their age.*

Rocks.—*Considered with regard to their composition, mineral masses take the name of* Rocks. *Thus we may say—*

Granitic rocks.
Calcareous rocks.
Argillaceous rocks, &c.

Formations.—*With reference to their origin, mineral masses are called* Formations, *a word used by several nations, but which belongs to the French language.*[2] *This term is only an abridged form of 'mode of formation,' and consequently implies of itself the idea of origin.*

The translation of the paragraph on the word *formation* in M. Dewalque's general report is the following. This paragraph was not adopted specially, but it agrees entirely with the preceding:

"The word *formation* implies the idea of origin and not of time. It should nots be employed as a synonym of system (terrain) or of stage (étage). But we may very well say: *eruptive formations, granitic, gneissic, calcareous formations, marine* or *lacustrine formations, chemical* and *detrital formations, &c.*"

After accepting the four paragraphs translated above from the French report, the meeting took up the consideration of the résumé and conclusions contained in the general report, adapted by M. Dewalque, Secretary of the Committee for the Unification of Geological Nomenclature, from the separate reports of the different national committees.

The opening paragraphs of this résumé deal with terms applied to mineral-masses in general with regard to age. After a very brief summary, the conclusions are stated in twenty-eight paragraphs, consecutively numbered; and of these paragraphs a certain number were discussed, altered, or amended, in several instances, and voted seriatim.

The following paragraph of the preliminary summary is essential to the clear comprehension of the various paragraphs. M. Dewalque writes:—

"Let us first examine that which concerns classification proper.

"All geologists agree in admitting about ten great series of strata, usually distinguished in French under the name of *terrains*, which are classed together

[1] That is of the planet, on which we live.

[2] That is, in this especial signification. It was agreed to give up the use of the term in the sense of rocks of any particular geological age.

in four or five groups of a higher grade, and which are daily being divided and sub-divided to a greater extent. What are the terms to be employed for the different grades of this classification? The following table, in which the second column corresponds to those divisions which we have just called "terrains," records the opinions of the different committees. In the absence of the American report, it has appeared useful to insert the proposition recently made by one of the members. In this case, as in that of the English propositions, we have considered that we might put in the first column, but between parenthesis, the expressions which it appears to us would be employed by the authors of the reports."

	1	2	3	4	5
"America[1] (Dana)	(Terranes)	Terrane	Group	Stage	Beds, Sub stage.
Belgium	Terrains	Terrain	Système	Étage	Sous-étage, assise
France	Terrains	Terrain	Étage	Sous étage	Assise.
Spain and Portugal	Série	Terrain	Membre	Étage	Zone.
Great Britain	(Systems)	System	Formation	?	?
Hungary	Formations	Formation	Étage	Assise	Couches.
Italy	Terreno	Systema	Piano	?	?
Switzerland	Série	Terrain (Gebilde)	Système	Étage (Stufe)	Assise.

It is unnecessary to translate at length the resolutions originally proposed by M. Dewalque, since nearly all were modified by the Congress. The terms he ultimately proposed for adoption, and those accepted by the Congress, were the following:—

1. For the first grade, that is, for a division of the whole series corresponding to palæozoic or mesozoic, no separate term was proposed. It was suggested that the plural of the 2nd grade should be used, and that geologists should write, e.g., *the secondary terranes*. The Congress, however, by a large majority adopted the term *groupe* (group).
2. For the second grade, the most important of all, that corresponding to such sub-divisions as Silurian, Carboniferous, Jurassic, &c., the term *terrain* was proposed in French, *terrane* in English, *Gebilde* in German. After a long discussion, however, the word *système* (system) was adopted by a considerable majority.
3. For the third grade, corresponding to such sub-divisions as upper and lower silurian, lias, dogger, neocomian, &c., the term *groupe* or *système* had been proposed in M. Dewalque's report. Both these terms having been otherwise defined, he next proposed *division*. This led to a long discussion and much difference of opinion, and another term, *série*, was supported by a large section of the members. The show of hands leaving the result doubtful, a ballot was taken, in which 52 votes were given for the word *série*, and 35 for *division*. The former term was consequently adopted; but, as it was shown that the corresponding expressions in German and Russian were inadmissible, it was finally agreed, after the subject had been reconsidered by the Council, that two terms,

[1] This is merely, it should be remembered, Mr. Dana's personal suggestion, and I was assured by the American geologists present at Bologna that the adoption of the term terrane would no more be approved by American geologists in general than by English.

série and *section*, might be employed, the German equivalent of the latter being *Abtheilung*.[1]

4. For the next lower grade of divisions, equivalent to associations of strata like those distinguished in the jurassic system by the names of Purbeck, Portland, Kimmeridge, Oxford, Bath Oolite, &c., the term *étage* in French and its equivalents (*stage* in English, *Stufe* in German, *piano* in Italian, *piso* in Spanish) were recommended in the report and accepted almost unanimously.

5. For the next sub-division the term *assise* was adopted by a large majority. In the report it was suggested that the corresponding terms should be *beds* in English, *Schichten* in German, *strata* in Italian. The choice of terms was, however, left open.

Paragraphs 7 and 8 of M. Dewalque's report were unanimously accepted. They run thus—

7. *The case may occur in which a geologist thinks it desirable to group together a certain number of assises into intermediate sub-divisions, which united together would form an étage. In such cases the intermediate sub-divisions would bear in French the name of* sous-étage.

8. *The lowest element of stratified systems is the* strate (*stratum*) *or* couche (*bed*).

The remaining paragraphs of M. Dewalque's report on terms of classification were not discussed, but, as they contain some valuable suggestions, a translation is appended.

9. The word *banc* (*bank*[2]) is applied to beds that are thicker or more coherent than those in the neighbourhood, or between which they are intercalated.

10. Inversely, thin or slightly coherent beds will be distinguished in French by the word *lit*.[3]

"11. The English plural *rocks*, and its corresponding terms *roches*, *roccie*, will have the same signification as *assise*: Ex.—*Llandovery rocks*, *roccie a Globigerine*.

"12. A *zone* is an assemblage of beds of inferior order, characterised by one or more special fossils, after which it is named.

"This expression is, therefore, synonym of the preceding one, from which it differs by the necessary addition of one or two names of fossils.

[1] Section is, of course, inapplicable in English, as it has another signification, which would lead to confusion. Division might be used, as it is the equivalent of Abtheilung.

[2] It is not clear whether this term is supposed to be applicable in English; but, if so, the supposition is erroneous. The English term *band* might be used, but it may be questioned whether the distinction is necessary.

[3] In a foot-note, M. Dewalque remarks that he has not attempted to propose the exact limitation of the English terms *bed* and *layer*. He admits that, whilst the exact English equivalent of *lit* is *bed*, the latter word is employed, as a rule, in the sense of the French word *couche*. If the distinction be really of sufficient importance to deserve recognition, there would probably be no objection to the use of *layer* as an equivalent term to *lit*.

"It may also happen that a 'zone' may be an 'assise,'[1] although the former is more frequently a division of the 4th order.

"13. The name of *horizon* is given to a bed or to a set (*série*) of beds which possess well-marked characters, by means of which they may be easily distinguished over large tracts of country.

"14. The word *depôt* (deposit in English) should only be applied to a mass produced during a period of time, or within an area limited and characterised by a certain petrographical homogeneousness."

It is as well that these various terms should undergo further consideration before any attempt is made to define them exactly.

Before proceeding further, it may be as well to show the application of the terms agreed upon to some of the Indian rocks. Taking, for instance, the cretaceous deposits of Trichinopoly, all belong to the upper *series* of the cretaceous *system*, which is part of the mesozoic *group*; and near Trichinopoly three marine *stages* are distinguished,—the Arialur, Trichinopoly, and Utatur *stages*. Similarly, the jurassic *system* of Cutch comprises four stages,—Umia, Katrol, Chari, and Patcham. Again, the great Gondwana *system* is divided into several *series*, of which the Damuda is one, and the Raniganj, Iron-stone shales and Barakar are the *stages* constituting that *series*. As an example of an "*assise*," the Talchir boulder bed might be quoted.

The next question for discussion was the use of chronological terms corresponding to the various divisions already defined. After much discussion the following were adopted:—

1. *Era*, corresponding to *group*.
2. *Period*, corresponding to *system*.
3. *Epoch*, corresponding to *series*.
4. *Age*, corresponding to *stage*.

All these were voted either unanimously or by large majorities, except the word epoch, which was only preferred to cycle by a single vote, the numbers on a ballot being 47 to 46.

It has, consequently, been determined that the correct expressions to use are—

Palæozoic or mesozoic *era*.

Silurian, jurassic, or eocene *period*.

Lias or neocomian *epoch*.

Kimmeridge or Purbeck *age*.

Of all the decisions, those which will probably appear least judicious are the significations given to the two words, *group* and *series*. Loosely as these expressions have hitherto been employed in English, the term *series* has, as a rule, been understood to imply a higher grade in geological classification, and to embrace a greater range of rocks than *group*. However, there is no insuperable objection to the reversal of these significations.

It had been proposed to consider the application of a systematic terminology to groups, systems, series, and stages; to let all names of systems, for instance,

[1] There appears to be some mistake here; I can only say that the above is an exact translation of the original.

terminate in...*ique* in French, and...*ic* in English, like Jurassic and Triassic, and to employ Cretacic, Carbonic, and Siluric, instead of the ordinary terminations. The Congress, however, very wisely refused to discuss the question.

It has already been stated that the meetings of September 29th and 30th were devoted to the colours and signs for geological maps. The greater part of the first day, however, was taken up by a discussion on the proposed general geological map of Europe. It is needless to enter into particulars on this subject, and it is sufficient to state the conclusions adopted. It was agreed that the map should be prepared at Berlin, and that the work should be under the supervision of a committee thus composed:—

MM. Beyrich and Hauchecorne, Executive Directors, for Germany.
M. Mojsisovics for Austria-Hungary.
M. Daubrée for France.
Mr. Topley for England.
M. Giordano for Italy.
M. de Moeller for Russia.
M. Renevier as the Secretary of the original Committee on map colouration.

The scale is to be $\frac{1}{1,500,000}$ (between 23 and 24 miles to the inch). The Committee to meet yearly at certain fixed times and places.

It may be added that the great delay that would be involved prevented the adoption of a larger scale. It is well to bear the scale of this map in mind, as it may be useful to prepare maps of other parts of the world, where practicable, on the same scale and with the same system of colouration, so that eventually all may be combined in one general geological atlas.

The next subject was that of the colours to be employed for systems of different ages. It may here be observed, that although no list of geological systems was approved, that upon which the scheme of colouration proposed in Prof. Renevier's report was based, comprised the following:—

Recent—	
Pliocene and Plistocene.	Tertiary or Cenozoic.
Miocene.	
Eocene.	
Cretaceous.	Secondary or Mesozoic.
Jurassic.	
Triassic.	
Carboniferous (including Permian ?)	Primary or Palæozoic.
Devonian.	
Silurian (including Cambrian ?)	
Precambrian.	

The following resolutions were first passed. Both are considerably modified from that originally proposed. All mention of the spectrum, on which the scheme adopted was originally said to have been founded, was omitted, and very justly, since neither the sequence, nor in some cases the colours proposed, are really those of the solar spectrum.

1. *The Geological Congress of Bologna consider that there is occasion to adopt an international agreement for the application of colours to the representation of geological formations. The series of colours adopted will be recommended to all countries and all geologists, especially in view of general works, but without any retrospective action upon maps in process of publication.*

2. *Rose-carmine* (pink) *will be preferred* (sera affectée de préférence) *for crystalline schists, whenever there is no certain proof that they are of Cambrian or post-Cambrian age.*

Bright rose colour may be reserved for rocks of pre-Cambrian age, and pale rose for crystalline schists of indeterminate age.

Both these resolutions were discussed at considerable length. The second resolution originally commenced thus: "Rose-carmine will be especially applied (*sera affectée spécialement*) to crystalline schists," and it was objected that the phrase should be modified so as to permit the application of the colour to other rocks in case of need. Another objection, that some pre-Cambrian beds may not be crystalline schists, was partially met by the form above adopted for the second part of the resolution. There is, however, some reason to suppose that further modification, and the use of additional tints, may become necessary in countries like North America and India, where several systems of rocks, known or believed to be of pre-Cambrian age, require distinction.

The third resolution was not discussed, as it was considered that further consideration was necessary before the classification of the palæozoic rocks, and the colours to be adopted for them, could be decided upon. The resolution ran thus.

3. Three colours will be applied to palæozoic systems:—

1*st*—Violet for silurian.
2*nd*—Brown for Devonian.
3*rd*—Dark grey for Permian and Carboniferous.

There was great divergence of opinion as to the claims of Cambrian and Permian to be distinguished by different colours, and also as to the tints to be employed. Thus the English Committee, whose report was received after the general report had been printed, recommended the following scale:—

Permian—Chalons brown.
Carboniferous—dark grey.
Devonian—Indian red.
Silurian—violet.
Cambrian—purplish violet.
Pre-Cambrian—purplish carmine.

The same committee proposed to distinguish altered (metamorphic) rocks, of whatever age, by lines or marks of red above the colour of the system.

The question of the colours to be used for palæozoic rocks was finally referred to the International Committee appointed to supervise the map of Europe.

In Resolution 4 on the colours for mesozoic rocks, an alteration was made on the proposal of M. Renevier himself in the adoption of violet instead of brick-red, the colour first proposed, for trias. The resolution thus modified was passed. It runs thus:—

4. *Three colours are applied to the secondary or mesozoic systems.*

1st.—Violet for trias.

2nd.—Blue for jurassic (lias may be distinguished by a darker blue).

3rd.—Green for cretaceous.

The cenozoic rocks were quickly disposed of. In M. Renevier's reports the colouration proposed was: bright yellow (gamboge) for eocene, chamois yellow (a kind of buff) for miocene, and pale sepia yellow with a light orange tint for pliocene and plistocene; modern formations to be left white, or represented by various signs on a white ground. The modified resolution proposed by M. Renevier and adopted was the following:—

5. *The tints of yellow will be applied to the cenozoic group, the higher beds being represented by paler shades.*

This was almost unanimously agreed to, but there was considerable discussion as to the selection of a special colour for quaternary beds. The question was ultimately left to the decision of the Map Committee.

The following three resolutions were then unanimously adopted:—

6. *The sub-divisions of a system may be represented by shades of the colour adopted, by white spaces being left* (réserves de blanc), *or by various markings* (hachures) *according to the particular requirements of each map, the only condition being that these markings be not opposed to the orographical characters, and that they do not render the map confused.*

The shades, either full or broken tints (pleines ou par réserves) *should be applied in the direct order of age, the darkest always representing the oldest beds.*

7. *The litteral notation (lettering) for rocks shall be based upon the Latin alphabet for sedimentary and the Greek alphabet for eruptive formations.*

The monogram of a system shall be formed as a rule by the initial capital letter of that system. The sub-divisions may be distinguished by adding to the capital initial letter, either the small letter that begins the name of the sub-division or a numerical exponent, or either one or the other as most convenient.

The numbers of numerical exponents ought always to be used in chronological order, one signifying the lowest, that is, the oldest sub-division.

8. *The use of palæontological, orographical, chronological, petrographical, and geotechnical signs, is recommended. Those which are, at the same time, the simplest, the most distinctive and the most easily remembered, should be preferred.*

It may be useful to give an illustration of Resolution 7. Taking, for instance, the Triassic system which would be represented by T, the three principal stages, Bunter, Muschelkalk, and Keuper, into which it is sub-divided, would be indicated by Tb, Tm, and Tk. The different associations of beds or "assises" in the Bunter would be represented by Tb_1, Tb_2, Tb_3, &c., Tb_1 being employed for the oldest.

This terminated the portion of the work relating to geological maps. The important question of the colouration of igneous rocks was reserved for further consideration.

The sitting of October 1st was occupied with the consideration of the rules for palæontological nomenclature, and was of less interest than the meetings of the previous days. It will be sufficient to give a translation of the resolutions voted.

1. *The nomenclature adopted is that in which each being is indicated by a generic and a specific name.*

2. *Each of these names is composed of a single word, of Latin, or Latinised; written according to the rules of Latin orthography.*

3. *Species may present a certain number of modifications connected together in time or space, and indicated under the names of* mutations *or* varieties[1]; *modifications, of which the origin is doubtful, are simply called forms.*

These modifications will be indicated, if necessary, by a third term, preceded according to circumstances, by the words variety, mutation *or* form, *or by corresponding abbreviations.*

(*a*) *A specific name should always be followed by the name of the author who established it. The author's name is placed between parentheses, when the original generic name is not preserved; and in this case it is useful to add the name of the author who changed the generic title.*

The same arrangement is applicable to varieties raised to the rank of species.

4. *The name assigned to each genus and each species is that under which it was first indicated, provided that the characters of such genus and species have been published and clearly defined. Priority does not go back beyond the twelfth edition of Linnæus*, 1866.

5. *In future, for specific names, priority will not be irrevocably acquired, except when the species is not only described, but figured also.*

It was thought undesirable to proceed further, most of the details being matters requiring regulation by biologists generally. The few rules passed differ principally from those adopted by M. Douvillé's report in refusing to acknowledge pre-Linnæan names.

At the closing meeting on October 2nd, Prof. Beyrich was named President of the committee of organisation for the next Congress at Berlin, and a fresh International Committee was appointed to continue the work relating to the unification of geological nomenclature. This committee consists of Messrs. Zittel for Germany, Neumayer for Austria, Dewalque for Belgium, Sterry Hunt for Canada, Vilanova for Spain, James Hall for the United States, Hébert for France, Hughes for Great Britain, Szabo for Hungary, Blanford for India, Capellini for Italy, Delgado for Portugal, Stefanesco for Roumania, Moeller for Russia, Torell for Scandinavia, Ch Mayer for Switzerland. This committee is to meet next year, 1882, together with the Map Committee, at the place and on the day fixed for the

[1] That is to say, (and the distinction is of great importance for geologists,) a mutation is a modified form of a species found in a bed of different age from that containing the typical form. A variety is a modification due, not to difference of geological age, but to geographical distribution. The distinction between these terms may be very usefully employed in geology. The original proposal of the term mutation, to express secular variation, is attributed to our old colleague, Dr. Waagen.

provincial meeting of the Geological Society of France; in the subsequent year, 1883, at the meeting of the Swiss Society of Natural Sciences.

Considering the work of the Congress as a whole, it cannot be stated that very much has been done towards the unification of nomenclature or of colouration and signs for geological maps. But still something has been effected; and if the extreme slowness of all legislative action in countries where the legislators are really a representative body be taken into consideration, the resolutions passed will not seem so meagre as at a first glance they appear to be. A commencement has, at all events, been made towards effecting both the main objects of this and similar congresses, and it is far better to pause and collect further evidence before coming to any final determination than to attempt to lay down rules, which, not being supported by a majority of geologists, will be generally disregarded. With reference to questions of nomenclature it should be remembered that many continental nations, and especially the French, aim at greater exactitude in the choice and use of words than is customary in English, and the importance of precise definition is therefore greater to them than to ourselves. Each system has its advantages, precision may be carried to excess, and so may laxity, even in the use of words; over-refinement, and the use of terms that do not express facts, may result from excess on the one side, and confusion from excess on the other, but unquestionably there is need for the definition of a considerable number of terms in addition to those already adopted whilst it can scarcely be said that any now accepted are unnecessary. The body of geologists throughout the world is large, and very widely scattered, and much time is necessary before the general feeling of the whole body can be ascertained; Moreover, the use of a congress like that of Bologna is by no means limited to making abstract resolutions. It is of vast importance, especially to those who have passed a great part of their lives in distant parts of the world like India, to meet the geologists of other countries and to exchange ideas.

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PROF. G. CAPELLINI.

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THE SOCIETY.

January 16th, 1882.

NOTICE.

SIWALIK FOSSILS FOR EXCHANGE.

Specimens of the teeth or bones of the following genera of Siwalik vertebrata are available at the Indian Museum in exchange for named teeth or bones from the pliocene, miocene, or eocene of Europe or America. Specimens of *Dinotherium*, *Mastodon longirostris*, or *Hippotherium gracile* are not required. Apply to R. Lydekker, care of Superintendent, Geological Survey of India, Indian Museum, Calcutta.

Dinotherium.
Mastodon (2 or 3 sp.)
Stegodon (3 sp.)
Loxodon.
Sus (2 sp.)
Hippohyus.
Hippopotamus.
Rhinoceros.
Aceratherium.
Hippotherium (2 sp.)
Equus.
Antilope.
Portax.
Crocodilus.
Gharialis.
Batagur.
Trionyx.
Emys.

RECORDS, GEOLOGICAL SURVEY OF INDIA,

Vol. XV, Part 1.

CORRIGENDA.

Page 25, line 2 from bottom, *for* 'in Chutia Nagpur,' *read* 'at Maleri.'
" 26, " 7, *for* 'lower,' *read* 'higher.'
" 45, " 15, *for* 'microscopically,' *read* 'macroscopically.'
" 45, " 15, *for* 'orthoclose,' *read* 'orthoclase.'

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 2.] **1882.** **[May.**

General sketch of the Geology of the Travancore State.—*By* W. King, D.Sc., *Deputy Superintendent (Madras), Geological Survey of India.*[1]

My last season's work (1880-81) was devoted to a general examination of the geology of the southern half of Travancore, and to a particular study of a small area of deposits which have been long known as occurring on the sea-coast, on the history of which I have written a separate paper (*infra*).

The development of the gold industry of Southern India having raised hopes of a similar auriferousness of the mountainous and coffee-planting districts in Travancore to that in Wainád, I was, at the very urgent request of the Travancore Government, induced to devote a considerable portion of my time to the examination of the region supposed to present the most favourable indications of gold-bearing rocks. The result of this was a report on the quartz outcrops of Parmand, in which I showed that the supposed reefs are to all appearance beds of nearly pure quartz-rock occurring with the other strata of the gneiss series, and that, though they locally give the very faintest traces of gold, there is no reason to expect that better results will be obtained. Practically, there are no auriferous quartz-reefs, as usually understood, in the area pointed out; neither do I expect that such will be found of any extent or richness in so much of Travancore as I was able to visit.

The geological examination of the country may be said to have extended over more than half of the territory—in reality, it consisted of various traverses over the country between Cape Comorin and the 9° 35′ parallel of north latitude; but I can generalize as to the lie and character of the very few rock formations over the country far to the northward, through visits which I had made in previous years in the Coimbatore and Malabar districts, and this season at Cochin, to which place I was called in connection with a commission of enquiry on the harbours, conducted by Colonel R. H. Sankey, C.B., in the hopes of being able to elucidate something regarding the well-known tracts of smooth-water off the coast at Narrakal and Poracaud.

[1] See map attached to the following paper on the Warkilli beds.

The Travancore State, though it has long had a very irregular eastern frontier, has now been settled as lying practically to the westward of the main watershed of the southern portion of the great mountainous back-bone or mid-rib of Southern India, which stretches from the low-lying gap of Palghat, below the Nilgiris, to within some 15 miles of Cape Comorin. Between this southern extremity of the mountain land and "The Cape," as it is distinctively called, there is an outlying hill mass which carries the water-shed rather to the eastward of the extreme southern point of India; but a low rocky spur does terminate the and, and outside of it, or a little to the eastward again and somewhat higher, are two rocky islets.

In the northern part of the country the mountain mass is very broad, but just south of the Parmand parallel (the northern limit of my proper work), the hilly back-bone narrows considerably, and becomes a lengthened series of more or less parallel ridges with lower and lower intermediate valleys. These are striking with the gneiss, or about west-north-west and east-south-east, there being at the same time a line of higher masses and peaks culminating the main ridge, from which the ribs run away, as indicated, to the low country.

The mountain land does not, as may be seen by any good map, run down the middle of the peninsula, but keeps to the westward; so that there is a broad stretch of low country on the Madura and Tinnevelly side, while that of Travancore is narrow. Then the mountains drop rather suddenly to the east; while they send long spurs down to within a comparatively short distance of the western coast. There is thus still, in Madura and Tinnevelly, a southerly prolongation of the wide plains of the Carnatic, which stretch round by Cape Comorin and join the narrower, though rather more elevated, low country of Travancore, Cochin, and Malabar.

This narrower and somewhat higher land of the west coast presents also unmistakable traces of a plateau or terraced character, which is best displayed about Trivandrum and northwards past Cochin into the Malabar country. South of Trivandrum these marks gradually disappear, the last trace being in the flat upand or plateau bordering the sea-shore at Kolachel. This more or less even surfaced tract of country has an elevation in its most typical parts of 150 to 200 feet above the sea; and it touches the shore in cliffs or headlands at two or three points, particularly at Warkilli, and in the Paupanchery hill south-west of Trivandrum.

To an observer travelling to Trivandrum across the Ariankow pass from Tinnevelly, the change from the parallel ridges and broken form of the lower hilly country to the comparatively smooth downs of Trivandrum is striking; though he would hardly see the generally terraced or plateau character until a more extended acquaintance had been made with the country.

Northwards from Trivandrum, there are narrow strips of absolutely low land, that is on the sea-level, marked by sandy and alluvial flats and long backwaters or lagoons. These widen out northwards from Quilon, until at Allepy (Aulapolay) there is a width of about 12 miles of such formations, with the very extensive back-water which stretches far past Cochin.

The rock formations are: first, and most prevalent and foundational, the gneiss series; and then on it, but only in a very small way, the *Quilon beds*, which are supposed to be of eocene age. These last are overlapped by the *Warkilli beds*, which certainly appear to belong to a different series, and are thus perhaps of upper tertiary age; they appear also to be equivalent to the Cuddalore sandstones of the Coromandel. Finally, there are the recent deposits.

The gneisses are generally of the massive grey section of the series, that is, they are nearest to the rocks of the Nilgiris, though they differ from them in being coarser-grained or more largely crystallized, and in being generally quartzose rocks.

So quartzose are they, that there are, locally, frequent thin beds of nearly pure quartz-rock which are at times very like reefs of vein-quartz. Often these beds are strongly felspathic, the felspar occurring among the quartz in distinguishable grains, or larger crystalline masses, giving the rock rather a granitic appearance. The only other region where I know of somewhat similar beds of quartz-rock occurring with other gneisses, is in the schistose region of the Nellore district. There, however, the quartz-rock becomes often a fine, compact quartzite; here, in Travancore, there are no approaches to such compact forms.

The common gneisses are felspathic-quartzose varieties of white or grey colours, very largely charged with garnets. A particular form of them is an exceedingly tough, but largely crystallized, dark-grey or greenish felspathic rock.

Massive hornblendic gneisses are not common. Indeed, hornblende may be said to be a comparatively rare constituent of the Travancore gneisses.

All the gneisses are more or less charged with titaniferous iron in minute grains; they are likewise, only more visibly, as a rule, highly garnetiferous. In fact, one might say that Travancore is essentially a country of garnetiferous gneisses. The garnets themselves are only locally obtainable, it being impossible to break them from the living rock, while they are generally decomposed or weathered. They are generally of small size, but are very rich in colour, the precious garnet being very common. Other minerals, such as red, blue, and yellow sapphire and jacinth, are found among the garnet sands so common on the sea-shore at certain places. The sea sands are also full of titaniferous iron grains. While on this subject, I may instance the beautiful and long known constitution of the shore sands at Cape Comorin, where, on the beach, may be seen the strongest coloured streaks or ribbons, of good width, of bright scarlet, black, purple, yellow, and white sands of all these minerals and the ordinary silica.

As will be seen further on, an enormous quantity of ferruginous matter is collected among certain forms of weathered gneiss and other rocks, the source of which is hardly accounted for in the apparent sparse distribution of iron in the gneisses. After all, however, an immense supply of ferruginous matter must result from the weathering of the garnets, when we consider that they are so generally prevalent in all the gneisses, and crowdedly so in very many of them.

The general lie of the gneisses is in two or three parallel folds striking west-north-west to east-south-east. There is, perhaps, rather a tendency of the strike more to the northward in the broad part of the hills, about Parmand, and on towards the Cochin territory. Thus, between Trivandrum and Tinnevelly on the west coast, or for some 12 to 20 miles inland, the dip is high to the south-south-west; inland of the terraced or plateau country, or among the first parallel ridges, there is a north-north-east dip; then, on the mountain zone, there is again a high dip generally to the south-south-west. Thus the inclination of the beds is generally high, right across the strike with a crushed-up condition of the folds; but they are often at a low angle, and the anticlinal on the western, or the synclinal on the eastern side, are plainly distinguishable. About Kurtallam (Courtallum), on the Tinnevelly side, the rise up from the synclinal is very well displayed, and in their strike west-north-westward into the broad mountain land, the beds of this place clearly take part in a further great anticlinal which is displayed in a great flat arch of the Parmand strata. With this widening out of the mountain mass, there is rather an easier lie of the strata.

Southwards from the Ariankow traverse just detailed, there is much crushing up of the beds; but they roll out flatter again towards the southern extremity, and there are good indications of a further synclinal to the south-south-west, in the northerly low dipping beds of Cape Comorin.

Foliation is very strongly developed: indeed it is here, practically, bedding and lamination, of which there are some wonderful exhibitions. At Cape Comorin, indeed, some of the gneiss in its weathered condition (not lateritized) is scarcely to be distinguished, at first, from good thick-bedded and laminated sandstones and flaggy sandstones.

There is no special development of igneous rocks either in the way of granites or greenstones, though small veins and dykes are common, generally running nearly with the strike of the gneiss. In southern Travancore, or north of the parallel of Trivandrum, there are stronger occurrences of granite, in which the mica is abundant and in largish masses.

The great feature about the gneisses in Travancore, and indeed also in Cochin and Malabar, is their extraordinary tendency to weather or decompose generally into white, yellow, or reddish felspathic clayey rocks, which, in many places and often very extensively, ultimately become what is here always called *laterite*. The evidences of this are, after all, only well seen in the field; but it may be stated here that these are seen principally in the constituent minerals, mainly the quartz, being still identifiable in much of the rock—in the lamination or foliation being also traceable—in the gradual change from the massive living-rock to the soft and finally hard, scabrous, and vermicular ferruginous clayey resultant called laterite—and in the thin, pale, and poorly ferruginous form exhibited by the weathering and alteration of the more felspathic and quartzose gneisses.

This altered form of the weathered gneiss occurs over a definite area which I have laid down approximately in the map. At the same time, the change from unweathered gneiss to this belt is not sharp; for long before the eastern limit of the more generally lateritized belt is reached, approaching it from the mountain zone, the great change has begun.

Very soon after one begins to leave the higher ribs of the mountains, and to enter on the first long slopes leading down to the low country, the gneiss begins to be weathered for some depth into a clayey rock generally of pale colours, streaked and veined with ferruginous matter, and having always an appreciable upper surface of scabrous or pisolitic brown-iron clay, which is, of course, probably largely the result of ferruginous wash and, less so, of ferruginous infiltration. Also, the ferruginous and lateritoid character is developed to a certain extent according to the composition of the gneisses; but, on the whole, there is no doubt that the upper surface generally over large areas is lateritised to a certain depth, irrespective of the varying constitution of the strata.

Then, as the rocks are followed, or crossed, westward, the alteration becomes more frequent, decided, and deeper seated; though still, all over the field, ridges, humps, and bosses of the living rock rise up from the surrounding more or less decomposed low-lying rock areas.

This generally irregular and fitfully altered condition of the gneisses begins at an elevation of about 400 feet above the sea, and thus it extends as a sort of fringe of varying width along the lower slopes of the mountains.

At a yet lower level, say from 200 to 150 feet, and so nearer the sea-coast, there is a better defined belt of more decidedly lateritised form of weathered gneiss, in which the unaltered rock occurs less frequently, and then always in more or less flatly rounded humps and masses, which never rise above a general dead level. This belt is, in fact, a country of undulating downs (where free from thick and lofty jungle), or tolerably uniform level stretches of forest land. Occasionally, it also shows a plateau surface, or it is broken into small and low flat-topped hills. Always it is very deeply indented by river and stream valleys, or even by some of the back-waters which have high and steep shores.

Further northwards, the plateau character of the lateritic gneiss belt is very well developed in Malabar.

It is remarkable of this coastal belt of country that its laterite (an altered, or ferruginously infiltrated condition of weathered or decomposed gneiss) is not to be distinguished from any other laterite, except that which is made up of obviously detrital material.

Whatever the laterite of Travancore or Malabar may have been originally, it is an useless form of the rock, being crumbly and soft as a general rule, and oftener of a red colour than brown. The character of the climate does, in fact, appear to militate against the changing of the red peroxide of iron in the rock, to the brown peroxide, during which change the proper cementing and hardening of the sound rock, such as that on the east coast or in the Deccan, is evidently brought about.

The next succeeding rock formations, namely, the Quilon and Warkilli beds, occur as a very small patch on the coast between the Quilon and Anjengo back-waters.

The Quilon beds are only known through the researches of the late General Cullen, who found them cropping out at the base of the low laterite cliffs edging the back-water of that place, and again in wells which he had dug or deepened for the purpose. I was myself not able to find a trace of them. They are said to be argillaceous limestones, or a kind of dolomite, in which a marine fauna of univalve shells, having an eocene *facies*, was found; and they occur at about 40 feet below the laterite of Quilon, which is really the upper part of the next group.

The Warkilli beds, on the other hand, are clearly seen in the cliffs edging the sea-shore some 12 miles south of Quilon, where they attain a thickness of about 180 feet, and have the following succession in descending order:—

Laterite (with sandstone masses).
Sandy clays (or lithomarge).
Sandy clays (with sandstone bands).
Alum clays.
Lignite beds (with logs of wood, &c.).

The bottom lignite beds rest on loose white sand; and nothing is known of any lower strata.

It will be seen how this set of strata has an upper portion, or capping of laterite, which is however clearly detrital. On the landward edge of the field of those Warkilli beds, there is in places only a thin skin, representative of these upper beds, of lateritic grits and sandstones lying directly on the gneiss, which is itself also lateritized; and it is very hard, as may be supposed, to distinguish the boundary between the two, unless the detrital character of the former deposits is well displayed. Thus, the upper part of the formation has overlapped the gneiss. It is also this upper portion which overlies the Quilon beds, which are also apparently overlapped.

These Warkili beds constitute, for so much of the coast, the seaward edge of the plateau or terraced country above described, and they present similar features. The Warkilli downs are a feature of the country—bare, grass-grown long flat undulations of laterite, with, about Warkilli itself, small plateau hills forming the higher ground—180 to 200 feet above the sea. These downs too and the small pláteaus or flat-topped hills, are partly of the Warkilli laterite and partly of the lateritoid gneiss.

Whatever form of denudation may have produced the now much worn terrace of the gneissic portion of the country, the same also determined the general surface of the Warkilli beds. Indeed, it gradually dawned on me while surveying this country, having the remembrance of what I had seen of the plateaus and terraced low-land in Malabar in previous years, that here, clearly, on this western side of India is an old marine terrace, which must be of later date than the Warkilli beds.

These are, as I have endeavoured to show in another paper, of probably upper tertiary age, and equivalent of the Cuddalore sandstones of the Coromandel. Hence this terrace must be late tertiary or post-pliocene, and it marks, like the long stretches of laterite and sandstones on the eastern side of the country, the last great or decided elevation of Southern India, prior to which, as is very probable, the Indian land rose almost directly from the sea by its Western Ghâts and had an eastern shore line which is now indicated very well by the inner edge of the Tanjore, South Arcot, Madras, Nellore, and Godavari belts of laterite and sandstone.

Mr. Foote has already generalised in this way for the eastern side of Southern India in particular; but I think he makes the elevation too great, including, as he does in his laterite deposits, patches of lateritised gravels and rock masses ranging up to a height of 500 feet at least, which are not so definitely part and parcel of the proper coastal developments.

The plateau form of the Coromandel areas has often already been commented on; but their connection with a terraced form of marine denudation is more clearly brought out, now that the evident conformation of the Travancore and Malabar low-land is ascertained.

The somewhat different level of the surfaces of these plateau lands on each side of the peninsula is also interesting in so far as there is an evident general very slight inclination of the whole to the south-eastward.

One more very small patch of variegated sandstones, but associated with scarcely any laterite, occurs in the Travancore country at Nagarcoil, about 12 miles north of Cape Comorin. I should certainly take this to be representative of the Cuddalore sandstones, so long as no positive evidence to the contrary turns up; and it may be the nearest connecting link between these rocks on the eastern coast and the Warkilli beds.

The recent deposits are the usual blown-sands and alluvial deposits of the low flats along the coast; an exceptional form occurs at Cape Comorin in the shape of a hard calcareous sandstone, which is crowded with true fossils and casts of the living *Helix vitata.* It appears to be simply a blown-sand, modified through the infiltration of calcareous waters. Loose blown sands are heaped over it now in places, among which are again thousands and thousands of the dead shells of the past season. The examination of this deposit has, however, been left to Mr. Foote, who has likewise reserved for his study other remarkable fossiliferous rocks of very late age which occur in this neighbourhood.

The Warkilli Beds *and reported associated deposits at* Quilon, *in* Travancore, *by* WILLIAM KING, D.SC., *Deputy Superintendent (Madras), Geological Survey of India (with a map).*

The rocks to be treated of in this paper are some lateritic sandstones, alum clays, and lignite beds, and other fossiliferous strata, which occur in the following order of succession :—

The Warkilli[1] *Beds:* apparently equivalent to the *Cuddalore sandstones* of the survey nomenclature.

The Quilon Beds: reported as having yielded fossils of presumably eocene age, and only known through the researches of the late General Cullen.

The Travancore low country, that is, so much of the western coast of southern India, as extends from Cape Comorin to within a short distance of

[1] Otherwise Wur-kullay or Varkalay.

Cochin, is slightly elevated and broken into low hills and ill-defined terraced land; thus differing very strongly from the far-stretching plains of the Carnatic, which touch the sea merely by a low bank of sand-hills to nearly as far north as Vizagapatam. At the same time, there is a narrow strip of the northern portion of Travancore which is just on the sea-level, and marked by a chain of extensive and lengthened back-waters or lagoons, the canal communication between which has, until lately, been barred by one small range of low hills between Cochin and Trivandrum. This barrier is the most important of the few approaches of the low terraced upland close on to the sea-shore; and it presents—looking at the absence of such features along the Coromandel, or their rarity along the west coast, the remarkable line of low and beautifully coloured cliffs of Warkilli. This barrier has now, however, been tunnelled so as to allow of complete and unbroken water communication, by which chance fresher sections—though unfortunately not deeper—were displayed of the rocks already so long exposed in the cliffs.

I believe the first idea of thus opening up a complete system of water communication may be attributed to the late General Cullen, then British Resident of Travancore; at any rate, he it was who first drew attention to the geology of this Warkilli barrier, and the occurrence of similar deposits near Quilon. General Cullen did not, it is to be regretted, publish any of his experiences, but he forwarded collections to Bombay, and communicated his observations to Mr. H. J. Carter, then Assistant Surgeon on the Bombay establishment, who embodied them in his well-known "Geological Papers on Western India." The previous literature is therefore, as far as is known, these writings of Mr. Carter; and his conclusions on the occurrence of these rocks, and the fossils said to have been obtained from them, were that they are preferably of eocene age. The following extracts from Mr. Carter's work (*l. c.* p. 741) give the information afforded by General Cullen, beginning with that for Warkilli itself:—

"The laterite and lignite cliffs of Varkalay, which are also near Quilon, that is, about 12 or 14 miles south, extend along the coast about 6 miles, varying in altitude from 40 to 60 feet. Below the laterite is a series of very beautifully variegated coloured sands and clays, and below them again the carbonaceous clays or shales and lignites. At the north end of the cliffs, where they are only 80 feet high, the lignite bed is level with the beach; but to the south, where the cliffs attain an altitude of 140 feet, there appear to be three or four successive deposits of lignite, each of which is from 4 to 6 or 8 feet thick. To ascertain, also, if this lignite bed extended inland, I sunk a well 20 feet in diameter, at a distance of about 100 yards from the cliff; and, after passing through 22 feet of laterite only (because the well was here sunk in a hollow), came to the lignite clays. I then sunk a small well, about 5 feet in diameter, on one side of the large one, to determine the thickness of the lignite bed, which was penetrated after 7 feet, meeting then with a bed of loose, white sand, from which the water immediately sprung up so rapidly as to oblige the people to leave off working. I have not found any traces of organic remains in these cliffs, nor any traces of limestone. The carbonaceous lignite beds abound with resin and iron pyrites (white), both, in lumps of considerable size. I have a lump of resin 10 inches in diameter.

"The variegated coloured sands that I have spoken of as lying between the laterite and lignite beds, are exceedingly beautiful—at least fifteen different and perfectly distinct tints.

It has strongly reminded me of what I have often heard, but never seen, except in geological drawings, viz., the strata of Alum Bay in the Isle of Wight."

The next place of examination was near Quilon; and it may as well be stated here at once, that I have myself only been able to carry on the uppermost member alone of the Warkilli beds so far north. It will be seen by the next extract (*l. c.* p. 740) that General Cullen was more successful in so far as he found other very important rocks, which were also fossiliferous.

"The first well I opened was on a laterite cliff or point, 4 or 5 miles north-east of the town of Quilon. Having observed some yellowish slabs of dolomite [argillaceous limestone?] at the base of the cliff or strand of the back-water, which there suddenly deepens to 40 feet, and therefore prevented my tracing it further downwards, I laid open several feet of the face of the cliff, and, still finding the dolomite slabs apparently passing under it, I then went above, for about 100 feet inland, and there sunk a large well, and met with the dolomite at the depth of about 38 feet.

"I then ascertained that the dolomite appeared everywhere to prevail below the laterite round Quilon, at a depth of about 40 feet from the surface.

"This was determined by the examination of wells in different localities, and by further sinking several which had not been carried down to that depth.

"I think there was a loose rubbly bed or stratum, of exactly the same composition as the compact limestone both above and below the slabs, and in which the greater number of the organic remains were found; but the limestone itself (though extremely hard and tough) also contained numerous specimens in the most perfect state of preservation.

"The limestone is of a bluish-grey inside, but externally, where exposed to the weather, of a dull yellowish colour."

This is all that is given of General Cullen's own descriptions; but Mr. Carter subsequently, in his notes, states that further information was furnished in one way or other about these Quilon deposits. Thus (*l. c.*, p. 741)—

"The specimens of limestone, too, which General Cullen formerly presented to the Society through Dr. Buist, not only bear the colour of the clay, but, with its imbedded tertiary shells, also contain portions of lignite indicating its intimate connection with it."

Again, in his discussion of the fossiliferous evidence of the tertiary deposits of Western India, Mr. Carter writes (*l. c.*, p. 743):—

"In this structure it will be seen that they resemble *Orbitolites Malabarica*, H. J. C. (Ann. and Mag. Nat. Hist., 2nd Ser., XI, p. 425, 1853), of the blue, clayey, argillaceous limestone of the coast of Travancore [1] * * ."

[1] On reference to this paper, I find that the locality of Orbitolites is moved further north, thus: "*Locality*—Abounding in an impure, bluish-green limestone (of the Pleiocene of [*sic*] formations), about 30 feet beneath the surface at Cochin on the Malabar coast, the shells of which, though deprived of their animal matter, are still white and pulverulent, or semi-crystalline." Mr. Carter, who is now residing in England, has very kindly allowed me to communicate with him on the subject of these Travancore fossils, and as regards this variation in locality, writes (7th November 1881):—"As regards the discrepancy in *locality* evidenced in my account of *Orbitolites malabarica*, it should be known that the specimens bearing this *Foram.* came into my hands while I was Conservator of the little museum of the Bombay Asiatic Society, as you may see by the extract, through the late Dr. Buist. This was some time before I began to correspond with General Cullen, and therefore long before I knew anything of the Quilon and Verkallay deposits; so it is not improbable that they, the specimens, were labelled "Cochin." At all events it is a mistake, for which I can offer no other explanation."

And at page 744:—

"Lastly comes the argillaceous limestone of the Malabar coast, not only abundantly charged with the Orbitolite just mentioned, but there again in company with *Strombus Fortisi*, together with *Cerithium rude*, *Ranella bufo*, *Cassis sculpta*, *Voluta jugosa*, *Conus catenulatus*, and *C. marginalus* (Grant, Geol. Cutch, Tert. Foss.); also *Natica*, *Turbo*, *Pleurotoma*, *Fasciolaria*, *Murex*, *Cancellaria*, *Ancillaria*, and *Cyprea*, all (new species?) closely allied in form to the figured shells of the eocene period. The orbitolite differs very little, except in size, from *Orbiculina angulata*, Lam. (Encyclop. Méthodique, pl. 468, fig. 3), from which I infer that the latter should also be included among *Orbitolites*, Lamarck."

I have given the above extracts here, because they go far to show that these fossils, or some of them, are those which were forwarded by General Cullen as having been procured from the beds underlying the Quilon laterite.

General Cullen's description of the occurrence of this "dolomite" and its fossiliferousness is so circumstantial that we must, until better negative evidence than that afforded by my unsuccessful search can be obtained, perforce believe that the rock and the fossils exist as described; hence, I will so consider this deposit in its relations with the Warkilli rocks.

The Warkilli beds consist of a series of sands and clays capped by laterite, giving the range of cliffs touching on the sea-shore. The highest part of the sea-face is at the southern end, between Warkilli village and Naddangúndi (Neddungunday), on the Anjengo back-water. Northwards the high ground runs down with the dip of the rocks, which is very gentle to the north, and thus the range of cliffs soon ceases in that direction until only a low scarped edge of rocks meets the sea at the Parravur[1] (Purra-ur) back-water. Thence, in the same direction, representative strata of the capping beds show only at some distance inland until Quilon is reached, where such rocks approach the shore and form at Tangacheri (Tungumshery) point a very low scarped headland, beyond which out in the sea are barrier reefs of the same rock.

It is not very easy to give the exact limits of the area of the Warkilli rocks, owing to the confusing way in which that peculiar form of rock alteration which gives rise to laterite,[2] or a rock resembling laterite, is developed, not only in these deposits themselves, but in the crystalline rocks or gneisses on which they lie and in the superficial rain-wash and debris covering both. Indeed, an ordinary

[1] A peculiarity of the Travancore topography is that there are few well-marked assemblages of dwellings answering to the villages of the eastern side of South India. The names given in the map apply rather to town lands, the cottages or farms being scattered and independent.

[2] The origin of laterite being still unsettled, it is as well that no opportunity should be neglected for keeping certain points in the investigation well to the fore. Only lately, I see that my colleague, Mr. F. R. Mallet, in his paper "On the ferruginous beds associated with the basaltic rocks of North-Eastern Ulster, in relation to Indian laterite" (Records Geol. Surv. of Ind., XIV, p. 148) writes with reference to a generalisation of Mr. W. J. McGee of Farley, Iowa, U. S. A.:—"But that laterite is a product of the alteration *in situ* of the underlying rocks is a view open to serious objections, which has been fully discussed by Mr. Blanford." Now this is striking at actual facts, against which no local or theoretical objections can be taken into consideration: for,—to put it plainly, and as long as we are unable to define strictly what shall and what shall not be called *laterite* among the strange ferruginous rocks which go by that name,—certain forms of this rock are actually and really an altered condition of the rock *in situ*. Such is the case

observer would say, that not only are the Warkilli downs composed of laterite, but that the greater part of the country far inland also consists of the same rock. Practically, there are thus three forms of rock here and in the neighbourhood which usually go by the name of laterite:—

1. Superficial ferruginously cemented debris.
2. The ferruginous, clayey, reddish or brown coloured, irregularly vesicular and vermiform scabrous rock forming the uppermost portion of the Warkilli beds, which is unmistakably detrital, and which I will call *laterite* in this paper.
3. The altered form of decomposed gneiss (called 'kabuk' in Ceylon), which I shall here write of as *lateritised* gneiss. This form always eventually shows traces of original crystalline structure and constitution.

Owing, then, to similarity of appearance and general ferruginous infiltration of these different rocks, it may be conceived how difficult it is to give close boundaries to the Warkilli beds. There is little trouble about their southern limit; but the eastern boundary is badly defined, it may range a short distance east or west of the line given in the annexed map, and particularly it may be much more sinuous than I have shown, and there may be a few insignificant outliers. About Quilon, I am exceedingly doubtful as to whether a good deal of lateritized gneiss may not be included in my field: thus it would be no easy task for me to persuade any one who had not had great experience of the behaviour of lateritic metamorphosis, that all the lateritic cliffs edging the Quilon backwater are not just as much laterite as those of the portion laid down on the map.

With these qualifications, the Warkilli rocks form a lenticular patch for about 22 miles along the coast, with a breadth, in the middle of the field, of about 5 miles; laterite alone at the Quilon end, and—by their gentle hade up to the south—laterite with underlying beds to a thickness of about 180 feet at the Anjengo end.

The series, as displayed in the cliffs at this end, is in descending order—

	Feet.
Laterite.—Ferruginous clays and sandy clays, in which are occasional, ill-defined masses and bands of coarse sandstone and incoherent sand, more or less vesicular, with irregular hollows and pipe-like or vermiform passages (discontinuous), very many of which are filled with white and pinkish fine clay; brown coloured, shading downwards to red, white, and yellow mottled; banded. Any bedding which may have existed is now much obliterated, and the upper brown band, which is more properly laterite, is not recognisable as a separate bed or capping	30 to 40

in Travancore, Malabar, and Ceylon, where I have over and over again traced the laterite (as it is called in Travancore) or the 'kabuk' (the Singalese synonym) into the living gneiss rock. I have held this view of what may be called the lateritization of gneiss with Mr. R. Bruce Foote (my colleague in Madras) for the last 20 years: our conclusions having been based on observations on the Nilgiris, Shevaroys, and other elevated regions in the Kurnool and Cuddapah districts; and my enlarged experience of the western coast and Ceylon have only confirmed it. Our experience of the Deccan laterites is not so extended, but we are agreed also that some of these must be products of alteration of the rock *in situ*.

	Feet.
Sands and sandy clays.—Red, yellow, white, and purple variegated sandy clays, with rather more distinct bands and masses of sandstone. Mottled in colour, but not so vesicular as the rock above, though still marbled with vermiform runs of finer clay (lithomarge of some writers). ... about	40
Pale red and white variegated and laminated sandy clays ...	10
Alum Clays.—Dark-coloured purple grey, compact clays with thin, scarcely appreciable, laminæ of iron pyrites, giving bright yellow alum efflorescence	5
Various coloured alum clays and sands; dark grey and buff at the bottom and yellow towards the top	20
Lignite beds.—An incoherent sandy bed of varying thickness, much laminated with brown loamy and clayey material, in which are many lumps and even logs of wood in various conditions of preservation. The wood is mostly blackened, and much in the condition of the 'bog-oak' of the Irish peat bogs	2 to 10
Dark, nearly black, clay; often rather peaty, or having patches of fine black vegetable matter, with particles and small masses of iron pyrites; containing, here and there, big logs of spongy, rotten, and, as it were, charred wood, and lumps of coarse resin . . . . about	5
Loose sands.—Coarse and white-coloured; only a few inches exposed.	

Thus, for the sea-cliffs, the section is in general terms:—

	Feet.
Laterite	30 to 40
Sands and sandy clays, or lithomarge	58
Alum clays	25
Lignite beds	7 to 15
Sands	...
Total .	120 138

Strong springs of clear fresh water issue at several points along the base of the cliffs from above the alum clay band. These are supposed to possess curative properties, and are accordingly of frequent resort.

The sections exposed in the cuttings and tunnelling of the barrier, which lie from a few hundred yards to half a mile inland, give a thickness of 30 to 70 feet for the laterite. This shades down into red, yellow, and whitish clayey sandstones, which are generally soft and wet, though at times hardened in bands and patches, and which have a variable thickness of from 40 to 90 feet owing to a wavy and uneven bottom. The alum clays are beautifully exposed in good beds, and for a long time they presented a fine display of colours—reds, blues, and greys, with strong bright yellow efflorescence, which have now, however, become blurred through exposure. In their lower sandy portion there is a good deal of wood. The thickness of the alum beds is about 20 feet. The proper lignite seam has about the same thickness as on the shore; but as the base of the tunnel does not run below them, there is no knowledge of the subjacent rock.

The outer and inner sections are thus substantially the same,—the differences being that the beds below the laterite, in the cuttings, are rather clayey sandstones than sandy clays; while logs of wood are found in the alum clays also.

As these beds are followed northwards along the shore, the dip gradually carries the lignite band below the beach, which is next bordered, for some hundred yards, by the alum clays, the upper edge of which is marked by the bamboo spouts let in above them at convenient places for carrying off the water of the sacred springs.[1] Then the clays, in their turn, run under a long flat beach, over which the water of the springs now flows directly, and about a quarter of a mile further on, the lowering cliffs are simply of the laterite, which rock finally ceases to show on the shore near Purravur.

The Warkilli capping is, however, continued inland in a north-eastward direction to the narrowing of the Purravur lagoon at Mailakád (Mylaked), but here all that exists of it is a very thin skin of coarse ferruginous grits and sandstones, which is lying directly on weathered and lateritised gneiss, the lower portions having thus been overlapped. Hence, if the clays, &c., are continued northward, they must lie deep under the lagoon and the sea.

From Mailakád other sandstone outcrops, associated with laterite, are traceable up to Quilon, under which place it might naturally be expected that either some trace of the Warkilli beds should be found, or that the laterite should overlie the gneiss directly. The only deposits, however, which I could find differing from the prevalent laterite, or its underlying lithomarge (common at the base of the low cliffs edging the back-water) is a loose, very coarse, yellow sand, occurring in a dried-up stream bed, or wide ditch, near the mosque between the civil town and the parade-ground, which is like some of the loose sands below the laterite band at Warkilli. I saw no limestone[2] or other calcareous rock answering to that described so circumstantially by General Cullen as cropping out at the base of the low cliffs north-east of Quilon.

Only representatives therefore of the upper portions of the Warkilli beds

[1] The water seam supplying the springs on the sea-shore was tapped by the tunnel operations, and there was a slight temporary decrease in the discharge. The leaking of the water in the tunnels and at the cuttings over the freshly opened alum clays, and the mixture of ferruginous wash from above, thus gave rise to considerable surmise as to the existence of natural chalybreate and other waters. Such are, however, only produced temporarily, though they will be collecting for a long time, and they might be found efficacious in some cases of the skin diseases so common on this coast.

[2] This reported occurrence of limestone and fossils by General Cullen is one of the strangest incidents of recorded observation which has taken place in India; for his account of it, and of his reasons for concluding that such a deposit underlies the Quilon laterite, is so clear that one can hardly suppose him to be mistaken; and yet there is no other evidence of its occurrence than the general statement as given by Dr. Carter. Not only have I not been able to find it, or the least trace of any calcareous debris—itself a very strange thing when we recollect that wells had been sunk inland—but the same disappointment had been already experienced by the District Engineer, Mr. Horsley, who is perfectly capable of distinguishing a calcareous rock, and, under the very urgent requirement of the works at Quilon for mortar, most diligent search for this argillaceous limestone or dolomite had been made. I believe, also, that Mr. Horseley had the advantage of employing the only guide left in a servant at the Residency, who used to accompany General Cullen in his excursions, and to work for him. This man, unfortunately for me, was at the time of my visit paralysed in his speech through continued fever and rheumatism, or other ailments, and unable to be moved.

occur at Quilon resting upon and apparently overlapping a set of fossiliferous beds only known through the researches of General Cullen.

The Warkilli strata are clearly of fresh-water or lagoon origin, being in fact very much after the style of the deposits now being laid down in parts of the present back-waters into which, at flood times, a great deal of drift wood and decaying vegetable matter is being carried along with silt clays and sands and ferruginous matter.

The fossiliferous argillaceous limestones under the laterite at Quilon are apparently very thin; and as the fossils described as having been obtained from them constitute an essentially marine fauna, they can hardly be considered otherwise than as belonging to a separate and somewhat older group than that which has thinned out over them. Each of them may be groups of a series or of a formation, or they may not; but the important feature is that they are separate groups; and thus I would differentiate the Quilon beds.

Reference to the "Geological Papers on Western India" already quoted will show how the whole series of Travancore deposits has been correlated with very similar deposits on other parts of the coasts of the Peninsula; as on this side going northwards, at Ratnagiri, Bombay, Broach, Kattiwar, Cutch, and Sind, and, on the other side, through the sandstones and laterite of the Coromandel, and the fossiliferous intertrappean beds near Rajahmundry. This correlation went too far, however, partly through this separate grouping not being known, and by a very natural straining at the comparison of a series of laterite and fossiliferous beds with the lateritic beds and limestones of Rajahmundry, which last now appear to be most reasonably of upper cretaceous age[1]: while the fossiliferous beds of Bombay northwards are of tertiary age.

Mr. Carter's correlation of the Quilon fossils with those of the Kattiwar, Cutch, and Sind beds, still stands, however, and he thus makes them out to be preferably of eocene age.

The Warkilli beds must then be either of the same age, or, if different conditions of deposition and apparent overlap go for anything, of perhaps a later tertiary age.

The evidence given by the wood at the base of the alum clays and in the lignite seam, is of little significance considering that perfectly fossilised wood occurs in the older alluvial deposits of the Godávari valley, which certainly appear to be far later deposits than these; though the very unaltered condition of the logs implies that they must be much newer than those containing the perfectly bleached and dull shells said to have been obtained from the Quilon diggings. To all appearance, indeed, this wood is very like the black-wood now growing in the Travancore forests; and it is so unaltered in good specimens that large pieces of furniture have been made from it which are scarcely distinguishable from that made out of the modern timber.

Again, taking up the original generalisation of Carter and other observers, but leaving the intertrappean beds of Rajahmundry out of count, there does not

[1] See Memoirs Geological Survey of India, XVI, pt. 3, and Manual of the Geology of India, Chapters XIII & XIV.

appear, so far as is yet known, to be any representative of the Quilon beds on the Coromandel, at least as far south as Madura. On the other hand, there is a strong lithological likeness between the upper portion of the Warkilli beds and the upper portion of the Cuddalore sandstones as at Vellum, in Tanjore, in the Red Hills of Pondicherry and Madras, and in the Nellore and Godávari districts; while they are all similarly situated as low-lying or not very elevated fringes bordering the sea-coast. There is also a possible link to this chain of coastal deposits on either side of India, in a small patch of red and variegated sandstones, with, however, very little show of laterite at Nagercoil, about 12 miles north of Cape Comorin.

Irrespective, however, of any argument from the association of the Warkilli laterite and sands with fossiliferous limestone having eocene affinities, a generally tertiary age has been given by us to the Cuddalore sandstones, through their discordant lie on the cretaceous rocks in South Arcot and on the traps and intertrappean beds of Rajahmundry. Hence, on the ground of lithological likeness, similarity of position, and, as far as it goes, general approximation of age, it may be assumed that the long supposed contemporaniety of the coastal laterite and sandstones is now fairly made out. Thus, as they are so continuously developed over large areas and occur in detached positions over so lengthened a coast line, without apparently being accompanied by or associated with these strange Quilon rocks, except in this one locality, they are indeed strongly separable from the latter and thus presumably of much later, or even upper, tertiary age.

I have had opportunities in previous years, and this season again, of examining the West Coast for some considerable distance further north, past Cochin and on to a few miles beyond Calicut; but so far there is no further representative of the Warkilli beds in particular, or the Cuddalore sandstones in general. It is quite true, however, that there are very extensive tracts of what is called laterite, as well as a remarkable terraced and plateau form presented by many of the low hills of these tracts. My examination of these showed, however, that all this lateritic country is merely one of a decomposed form of gneiss, and that the capped character of the plateaus in the neighbourhood of Beypur and Calicut, for instance, is due to the denudation of an originally planed-down terrace of gneiss into detached plateaus, the upper surfaces of which are altered and lateritized to a certain depth.

There may be detached patches of the Warkilli beds north of Calicut as yet unknown, but the first occurrence of rocks resembling them, of which there is any record, is in the neighbourhood of Ratnagiri, of which the following section is given by Dr. de Crespigny (1856) [1]:—

"Soil and detrital conglomerate	(a few feet).
Laterite (soft below)	35 ft.
Compact iron stone	1½ "
Lignite	} 27 "
Blue clay	
Water, yellow gravel	
Trap."	

[1] Carter's Papers, *op. cit.* p 723, foot note.

Mr. C. J. Wilkinson, when attached to the Survey (in 1863), visited this part of the country, and thus describes[1] the occurrence of these rocks:—

"At Ratnagherry, &c., in well and other sections, the trap is found to be overlaid by a thickness of a few feet of white clay, imbedding fruits and containing thin carbonaceous seams composed for the most part of leaves. This is separated from the soft laterite above by a ferruginous band about an inch thick, having much the appearance of hæmatite. It is vesicular, the cavities being filled by quartz, &c. The soft laterite soil above hardens on exposure, and this rapidly. It is very thick here and along the sea coast, trap only becoming exposed in the deep sections and at the base of the cliffs."

It cannot, I think, be doubted that here is a true representative of the Warkilli beds; and as the traps on which the rocks lie are generally flat, it is not to be expected that any representative of the Quilon beds shall be found.

Note on some Siwalik *and* Narbada Fossils *by* R. Lydekker, B.A., F.Z.S., *Geological Survey of India.*

1. *The Narbada Hippopotamus.*

In Falconer and Cautley's great work on the fossils of the Siwaliks, there are figured numerous remains of hippopotami from the pleistocene deposits of the Narbada valley. Among these remains all are referred to a species named *Hippopotamus palæindicus*, with the exception of four lower jaws,[2] which are referred to a second species under the name of *H. namadicus*. Unfortunately neither of these species was ever described, so we are compelled to rely upon Falconer's figures and occasional notes. It is stated[3] that *H. palæindicus* is allied to the living African hippopotamus, but is distinguished by the median pair of incisors being slightly smaller than the outer; the reverse being very markedly the case in the living species. This species had only two pairs of lower incisors, and was accordingly referred to Falconer's sub-genus *Tetraprotodon*. These teeth are of large size.

In *H. namadicus*, which, as already said, is known only by the lower jaw, there are always six incisors, which in some specimens (F. A. S., pl. LVIII, figs. 1, 3,) are sub-equal in size, and placed in the same horizontal line; while in others (*Ibid*, pl. LVII, fig. 12; LVIII, fig. 2), the second pair of incisors is rather smaller than the others, and thrust somewhat above their line. All the incisors of this form are smaller than those of the tetraprotodont form.

If no other specimens than those figured in the "Fauna Antiqua Sivalensis" were in existence, I should have little, if any, doubt as to there being two species of Narbada hippopotami. There are, however, two specimens of the mandibles of hippopotami in the Indian Museum, from the Narbada deposits, which lead me to have very grave doubts on this subject.

The first of these specimens (F. 147) has three pairs of incisors of sub-equal size, and must therefore be referred to Falconer's *H. namadicus*. The second

[1] Records G. S. of Ind., IV, p. 44.
[2] Pl. LVII, fig. 12; LVIII, figs. 1, 2, 3.
[3] "Pal. Mem." Vol I, pp 21, 147, 497.

pair of incisors are, however, more raised above the line of the others than in any of Falconer's specimens.

The second specimen (F. 148) has two pairs of very large and closely approximated incisors, and therefore agrees with Falconer's *H. palæindicus*. In the upper angles between these large teeth, there are, however, wedged in, two very minute teeth, corresponding to the second pair of incisors in *H. namadicus*. The vertical diameters of the first, second, and third incisors in this jaw are respectively 1·96, 0·59, and 2·0 inches; while in the other specimen they are 1·2, 0·9, and 1·33 inches. The specimen No. F 148 must certainly be referred to *H. palæindicus*, but the presence of the minute pair of second incisors connects it so closely with those forms of *H. namadicus* in which that pair of teeth is, so to speak, partly squeezed out of the way by the others, that it becomes a question whether the latter species can be maintained.

It is true that in the typical tetraprotodont forms, and in No. F 18, the first and third incisors are much larger than in typical hexaprotodont forms; but this might be accounted for by the greater space for growth which these teeth obtain in the tetraprotodont form.

On the whole, it would perhaps be rash to say positively that there is only one species of Narbada hippopotamus; but, taking into account that only one form of skull could be distinguished by Dr. Falconer, and the variations above noticed in the lower incisors, such was not improbably the case.

The tetraprotodont form of the Narbada hippopotamus seems to be distinguished from the African species by having the two pairs of incisors of sub-equal size, or the outer larger than the inner. In the living species the inner incisors are generally very much larger than the outer. The hexaprotodont form in which the lower incisors are of sub-equal size, and placed in the same horizontal line, seems to agree very closely with the older *H. sivalensis*, and I am not aware how they can be distinguished.

The Narbada hippopotamus, whether belonging to one or more species, shows a clear instance of the evolution of a tetraprotodont from a hexaprotodont form, after the general law of progression from the generalised to the specialised. These animals, further, most clearly connect the Siwalik with the living form, and may thus indicate the line of descent of the latter.

The above conclusions indicate decisively that Falconer's sub-genera *Hexaprotodon* and *Tetraprotodon* must be abolished, as their distinctive characters are found in the same species. They further indicate that it is almost certainly the second pair of incisors which is suppressed in the African hippopotamus; a fact which may prove of some importance in determining the homologies of the incisors in other ungulate mammals (*e.g.*, *Rhinoceros*) in which the whole of the typical series is not developed.

2. *Structure of molars of Mastodon sivalensis.*

A much worn molar tooth of *Mastodon sivalensis* from the Punjab in the collection of the Indian Museum,[1] which has been recently cut and polished, shows

[1] No. A. 258.

a peculiarity in the arrangement of the enamel, not previously observed, as far as I am aware, in the teeth of the Proboscidia. The enamel, in place of simply investing the cones, or denticles of the crown, as a regular cap, is thrown into numerous folds, placed at regular intervals from one another, penetrating deeply into the dentine of the cones, and converging towards their centres. The horizontal section of one of these cones exhibits a structure intermediate in respect to the depth of the foldings of the enamel, between that of the teeth of *Ichthyosaurus* and *Labyrinthodon.*[1] The infoldings are considerably deeper than those in the former genus, and if the symmetry of the cones were not interfered with by mutual adpressure, these infoldings would present a regular convergence towards the centre as in *Ichthyosaurus.* A second cut specimen exhibits a similar structure.

I have not observed this structure in the molars of any other species of mastodon; and from the statement of Professor Owen, that "there is no instance in the mammiferous class of these [enamel] folds converging at regular intervals all round the circumference towards its centre,"[2] it would appear that the molars of *Mastodon sivalensis* are quite peculiar in this respect, and exhibit a homology between the teeth of mammals and reptiles not previously known to exist.

3. *Captain Searle's Perim Fossils.*

A small collection of vertebrate fossils from Perim Island, collected by the late Dr. Wilson, has recently been presented to the Indian Museum by Captain Searle, Superintendent of Marine, Calcutta, which may be appropriately noticed here. The collection comprises a tooth of *Mastodon perimensis,* and a broken one of *M. latidens.* A lower jaw of *Acerotherium perimense,* and one of another member of the same family, showing the symphysis, and identical with the mandible referred to *Rhinoceros sivalensis* in the "Palæontologia Indica":[3] this form is new to Perim Island. Several limb-bones of elephants and rhinoceroses are also among the collection. There is a horn-core of a large ruminant, generically indeterminable. There are also two fine specimens of the cranium of *Gharialis gangeticus,* and the imperfect humerus of a large species of tortoise (not *Colossochelys*), new to these deposits.

With these additions the fossil vertebrate fauna of Perim Island includes the following forms[4] :—

Mastodon latidens, Clift.
„ perimensis, Falc. and Caut.
„ pandionis, Falc.
Dinotherium indicum, Falc.
Hyotherium, sp.
Sus hysudricus, Falc. and Caut.
Bramatherium perimense, Falc.
Camelopardalis sivalensis, Falc. and Caut.

[1] See Owen's "Odontography," pl. LXIV B.
[2] *Loc. cit.*, p. 201.
[3] Series X, Vol. II, pt. I.
[4] This list may be taken to supersede that given on page 348 of the "Manual."

Antilope, sp., and other ruminants.
Capra perimensis, Lyd.
? Rhinoceros sivalensis, Falc. and Caut.
Acerotherium perimense, Falc. and Caut.
Hippotherium theobaldi, Lyd.
Crocodilus palustris, Less.
Gharialis gangeticus, Gmel.
Colossochelys atlas, Falc. and Caut.
Testudo, sp.
Emyda, sp.
Trionyx, sp.

4. BAGARIUS YARRELLI, *from the Siwaliks.*

In the sixth volume of the "Journal of the Asiatic Society of Bengal"[1] a portion of a fossil ichthyopsidan skull is described and figured by Dr. Cantor as that of a gigantic batrachian. It was discovered by Colonel Colvin in the Siwaliks of Náhan, and is now in the collection of the Indian Museum[2] In 1844 this specimen was again described and figured by Dr. M'Clelland,[3] who showed that it belonged to a siluroid fish, and probably to *Pimelodus.*

At a subsequent date reference was made by myself to the specimen,[4] when it was argued that it was improbable that it belonged to *Pimelodus*, since that genus is confined to the West Indies and Africa. In Dr. M'Clelland's time, however, the genus was less strictly defined and comprehended many Indian forms, and it will be shown below, that in this wider sense Dr. M'Clelland's determination was correct. It was suggested in my notice that the specimen might belong to the genus *Chaca.*[5]

Thus the matter remained till a few weeks ago, when a huge siluroid, caught in the Hughli, was brought to the Indian Museum by its captors. On seeing this gigantic fish I was at once struck with the resemblance of its head to the fossil skull, and accordingly made arrangements for comparing the two skulls as soon as the recent fish was macerated. This comparison I have lately made, and I find that the fossil (of which Dr. Cantor's figure gives a very good idea) comprehends the preorbital part of the skull and agrees precisely in every detail, both of shape and size, with the skull of the recent fish. The agreement between the two is so close that I have no doubt but that they are specifically identical.

An examination of the recent fish shows it to be *Bagarius yarrelli*, Sykes, which according to Dr. Day,[6] inhabits "the large rivers of India and Java, des-

[1] P. 538, pl. XXXI.

[2] No. E, 155.

[3] "Calcutta Journal of Natural History," Vol. IV, p. 83, pl. IX.

[4] Journal of Asiatic Society of Bengal, Vol. XLIX, pt. II, p. 15.

[5] This suggestion was mainly made on the supposition that the fragment of the skull was more complete than it is, and consequently that the skull was very broad and short.

[6] "The Fishes of India," Vol. II, p. 495, pl. CXV, fig. 3.

cending to their estuaries. It attains 6 feet or more in length." The present specimen was just under 7 feet in length. The old name of this fish was *Pimelodus bagarius*. The identity in size of the recent and fossil skulls probably indicates that the two specimens had attained the full development of which the species is capable. The extreme length of the recent skull is 21·4 inches.

The determination of another existing species of vertebrata in the Siwalik fauna is a matter of extreme interest, and confirms the inferences previously drawn as to the geological age of this fauna. The living species now identified from the Siwaliks are *Crocodilus palustris, Gharialis gangeticus, Pangshura tectum, Emyda vittata*, and *Bagarius yarrelli*. We shall see below that *Python molurus* may not improbably be added to this list.

5. *The Siwalik Python.*

On page 20 of my paper in the "Journal of the Asiatic Society of Bengal" already quoted, reference was made to some ophidian vertebræ in the Indian Museum[1] from the Siwaliks of Sind and the Punjab, which were said to resemble those of *Python*. I have lately submitted these vertebræ to a careful comparison with those of the living Indian *P. molurus*, and can detect no difference between the two. Most of the fossil vertebræ belonged to pythons of not more than 5 or 6 feet in length, but an early dorsal[2] indicates an animal of upwards of 15 or 16 feet in length. It would, perhaps, be rash to say positively, from the evidence of these vertebræ, that the Siwalik python was specifically identical with *P. molurus*, but it is quite probable that such was really the case.

6. NARBADA AND SIWALIK MOLLUSCA.

Mr. Geoffrey Nevill, our specialist on Indian terrestrial mollusca, has been kind enough to examine the small collection of land and fresh-water shells from the pleistocene of the Narbada and Jamna, and also from the Siwaliks, contained in the Indian Museum. It may be observed that lists of shells from the Narbada beds have already been published by Mr. Theobald in two separate papers,[3] and that the specimens mentioned in the second of these papers are those submitted to Mr. Nevill, whose determinations differ somewhat from those of Mr. Theobald. Of Siwalik shells the Indian Museum has but three species.

A note on shells from these deposits is given in the "Palæontological Memoirs,"[4] but the knowledge of living Indian terrestrial mollusca was then so imperfect that the note is practically valueless. It would appear from this note that a considerable variety of Siwalik shells were obtained, which are probably now in the British Museum, and it is much to be desired that they should be submitted to the examination of some competent authority for determination.

[1] Nos. E205-206.

[2] No. E 206.

[3] Mem. Geol. Surv. India, Vol. II, p. 284, *et seq.* *Supra*, Vol. VI, p. 54, *et seq.*

[4] Vol. I, p. 389.

The shells from the Jamna pleistocene mentioned in the following list were collected, and presented to the Indian Museum by Mr. John Cockburn :—

Name.	Narbada.	Jamna.	Siwalik.	REMARKS.
Melania tuberculata, Mül., v. pyramis, Bens.	+	+	...	
Planorbis compressus, Bens.	+	...	...	
" convexiusculus, Hut.	+	...	...	
" exustus, Desh — ? var.	+	...	...	
Paludina bengalensis, Lam.	+	...	...	
" dissimilis, Mül.	+	+	...	
Helix proxima, Eish	+	...	...	
" asperella, Pfr.	+	..		
Buliminus (Cylindrus) insularis, Ehr.	+	...	+	
Corbicula, sp. 1	+	...	...	Referred by Mr. Theobald to *C. cor.*
" " 2	+	...	...	Very small, with large ridges.
" " 3	...	...	+	Large: Mr. Nevill cannot identify with any living form.
Unio marginalis, Lam.	+	...	+	
" favidens, Bens., var. 1	...	+	...	Near *U. marcens*, but cannot be identified with any living variety.
" " " var. 2	+	...	...	Near *U. wynegangensis*, Lea.
" " " var. 3	..	+	...	Near *U. triembolus*, Bens.
" wynegangensis, Lea	+	...	...	
" shurtlefianus, Lea	+	...	...	
" indicus, Sow., var.	...	+	...	
" macilentus, Bens., var.	+	...	...	
" corrugatus, Mül., var.	...	...	...	

The most important fact to be gleaned from this list is that two species, *viz.*, *Buliminus insularis* and *Unio marginalis*, can be traced without variation from the Siwaliks, through the Narbada to the present time: both are still living in the Narbada valley. A Siwalik species of *Corbicula* is considered by Mr. Nevill to be probably extinct, while a probable variety of *Unio favidens* from the Jamna seems to differ from any living variety, though great stress cannot be laid on this point owing to the uncertainty of the specific character of the members of this genus.

7. GIGANTIC HYOPOTAMUS, *from Sind.*

From the lower Manchhars of the Bhugti hills, north of Sind, Mr. W. T. Blanford has lately procured some upper and lower molars of a gigantic species of *Hyopotamus*. These teeth are far larger than those of any described species, nearly equaling in size the molars of *Anthracotherium magnum*. They will be described subsequently in the "Palæontologia Indica."

On the Coal-bearing rocks *of the valleys of the upper* Rer *and the* Mand *rivers in Western Chutia Nagpur. (With a map.)*

By V. BALL, M.A., F.G.S., *Geological Survey of India.*

The following is a record of observations made in the season 1870-71 during a traverse of the areas of coal measures which intervene between those of the Bisrampur field on the north and the Raigarh and Hingir coal-field on the south. Fuller and more detailed examination of these last mentioned fields in subsequent seasons enabled separate accounts of them to be published,[1] but as the details, now about to be given, were of incompleted areas, their publication was held over until such time as the whole area between Raigarh and Korba could be thoroughly explored and described as a united coal-field. Except a brief summary in the Manual of Geology[2] taken from the following notes, nothing has been published regarding these areas, so that in view of the present importance attaching to the existence of coal in this region and in anticipation of future more detailed work, it is thought that the following instalment of information may be of value as it serves to link together the coal measures of Sambalpur, Central Sirguja, and Korba, in Bilaspur.

Lakhanpur Field.

This field, as at present known, is a small area of about 50 square miles, situated in the south-west corner of central Sirguja and to the south of the Pilka hills.

On the north it is bounded by the Pilka fault, described in the Bisrampur report; on the north-east by metamorphic rocks, the boundary being probably natural. On the south-east also by metamorphic rocks, the boundary being here faulted; on the south partly by metamorphic rocks and partly by Talchirs which connect it with the Rampur field. The western extension has not yet been examined.

Within the limits of this area there are no hills; a thick covering of alluvium obscures all the rocks except in the river sections, of which, however, there are fortunately a good many.

The rivers are the Rer or Arand and the Goinghata with 5 or 6 direct and indirect tributaries, all of which afford sections.

The rocks exposed all belong either to the Talchir or Barakar groups, there being no representative of the upper sandstones found in this area.

TALCHIRS.—A strip of Talchirs, not very distinctly seen, occurs on the north-east boundary of the Barakars; the only clear section of these rocks occurs in the Goinghata west of the Satpara and Mendra road; they consist there of green sandstones, shales, and the boulder bed.

Some Talchir rocks are also exposed in the bed of the Goinghata near the

[1] Raigarh and Hingir, Rec. Geol. Surv. of India, Vol. IV, pp. 101 to 107; Vol. VIII, pp. 102 to 121, Vol. X, pp. 170 to 173, Bisrampur *op. cit.* Vol. VI, pp. 25 to 41.

[2] Part I, p. 207.

deserted village of Rukra, their relationship to the Barakars on the north and south I had not time to ascertain.

In the Rer or Arand on the south-west, Talchirs crop up, and passing southwards connect this field with the one further south (Rampur), which is traversed by the higher reaches of the same river.

In the jungle near the village of Mudesa, east of this field a small outlier of Talchirs was noted. Its limits were not traced out.

BARAKARS, *Goinghata section.*—North-east of Mahadeopara there are some slates and quartzites apparently of sub-metamorphic age. South of these there is an interval through which the fault already mentioned, probably passes. Nearly east of the village there are Barakar sandstones which include a seam of carbonaceous shale, and from under which the Talchir rocks, just alluded to, crop out and continue in the bed of the stream for about half a mile, after which they are again covered by apparently the same section of Barakars.

The repeated seam appears to contain a small quantity of poor coal, after which there are two seams which contain carbonaceous shale only. In the reach north-west of Parsori there is a seam containing about 3 feet of stony but burnable coal. The base is hidden. North of Ambera there is a seam badly seen in the bed of the river; it contains at least 2′ 4″ of tolerable coal.

South of the mouth of the Khekra stream the only rocks which are exposed are sandstones and grits, save a very fine trap dyke which crosses the river with a strike of 15° N. of E.—15° S. of W. and maintains that direction steadily as far as the Rer, being seen in all the intervening streams, but not in the intervening alluvium-covered high ground.

Khekra section.—In the Khekra river from its junction with the Goinghata to the point north of west of Lapatra, where it is intersected by the boundary of the gneiss there are exposed a few sandstones, the trap dyke, and about a foot of coaly shale.

Chandnai river.—This river and its tributary, the Chulhot, have not been plotted in detail on the map. Instead of the peculiar winding courses which they follow, they are represented as consisting of long rectangular reaches and bends. It is consequently difficult to represent faithfully the position of the coal seams.

Between the mouth of the Chandnai and the village of Kutkona, there is a much broken section of sandstones in which three outcrops of coal seams occur. In the first, 1′ 6″ of coal is exposed; some of the blocks derived from it consist of very good coal. Neither of the others are of very promising character, but the one near the mouth of the Gumgara is evidently of some size and may contain good coal, though it is not now exposed.

Trap occurs in the bed of the river about one-third of a mile from Kutkona. Just below the village the large trap dyke mentioned above crosses the stream disturbing in its passage, but not to a detrimental extent, the finest coal seam which occurs in this area.

Where most clearly seen, this seam (the base being hidden) consists of about equal parts of good, fair and burnable shaly coal, in all a thickness of 5′ 6″ capped by a massive bed of about 30′ of sandstone.

Whether the position of the dyke is coincident with a fault which has flung the coal on the south, I could not ascertain, but even if it has, the seam in all probability extends throughout a considerable area on the north and west.

The branches of the river which meet close to this traverse a broken section of sandstones for about 2½ miles, after which the gneiss rocks come in. In the eastern branch, near the village of Sirkotonga, the boundary is seen very clearly and is clearly faulted. In the western the boundary is completely obscured by alluvium.

The Rer or Arand section.—In the Rer river west of Jamgula there are some sandstones, apparently of Talchir age. From this northwards many of the reaches expose no rocks whatever; but those which are seen are Barakar sandstones and grits; they are for the most part horizontal. The above-mentioned trap dyke is again seen in the bed of the river to the south-west of Bagdari.

Should coal ever be required in this neighbourhood, I think there is a good prospect of its being found of fair quantity and quality at no great depth and in approximately horizontal beds.

Borings made within a mile radius of Ambera and Kutkona would probably give a fair test of the capabilities of the area.

Rampur Coal-field.

The area for which the above name is proposed is bounded on the north by the Lakhanpur gneiss, on the east by the Mainpat, on the south it passes into the Mand area described below, on the west it is connected with the great area of coal-measure rocks which stretches to Korba.

I do not attempt to make any estimate of area, as my observations were simply confined to the vicinity of the route-track from Lakhanpur to Matringa.

Passing west and south from the Lakhanpur granitic gneisses, which run under the sandstones and trap of the Mainpat, the valley of the Rer or Arand is reached. At Patrapali, west of Lakhanpur, and following it up to its source, the river at first alternately traverses Talchir and Barakar rocks; but in the highest reaches the upper sandstones are exposed.

TALCHIRS.—In the Arand between Chainpur and Jajgi there is a broken section of Talchirs consisting chiefly of sandstones; shales and the boulder bed are, however, not absent. Above (*i.e.*, to the south of) Jajgi for about 2 miles, no rocks are seen, but beyond Ubka, there are some Barakar sandstones, and an indistinct outcrop of Talchirs (?) appears at the road crossing to Lachmanganj. This apparently rests on some quartzite gneiss which strikes into the bed of the river a little further on.

For 5 miles beyond this the river shows no signs of any Talchirs, but it is of course possible that some may exist as there are many long sand-covered reaches.

South-west of Lipingi there are Talchirs, and they crop out at widely separated intervals for about 3 miles.

The boundary of the Talchirs strikes the river again a little above its junction with the Sagar stream, and crosses it a little beyond the high road ghât. The

Talchir rocks occur from this point for about a mile eastwards, after which they are covered by some sandstones which may be either Barakars or upper sandstones. This point remains still to be determined.

Beyond the village of Kesma again Talchirs (or rocks lithologically so like them as to be undistinguishable) re-appear. Fragments of coal or coaly shale occur sparingly in the bed of the river, but there is no trace of Barakar rocks in the main stream and the trap-capped hills on either side of the valley appear to be altogether comprised of the upper sandstones, so that I am inclined to believe that the coal, &c., must be derived from layers in the latter

BARAKARS.—The first or most northern outcrop of Barakars is exposed in the reach of the Arand south of Ubka, where there are sandstones resting on coaly shale. Several other outcrops occur in the river up to the road crossing.

In the country west from this there are several peculiarly shaped hills, notably one called Ramgarh. The summit of this hill is 3,206 feet above the sea. The upper portion consists of a massive rectangular block of the upper sandstones, which are here from 550 to 600 feet thick; these rest on a pedestal of Barakar rocks, the highest bed of which is a coal seam containing about 4′ 6″ of rather stony coal. The summit of the hill is capped by trap. Owing to the antiquities, cave temples, &c., several notices of it have been published, and the existence of the coal seam has been referred to by Colonels Ouseley[1] and Dalton.[2] A description of the hill has also been published by the present writer.[3]

Returning to the Arand section. In the vicinity of Tunga, there are some slabs of coaly shale which appear to have been derived from no very distant source. As no seam appears in the Arand close by, it is probable that one is exposed in some of the tributary streams, possibly the Gerua, as some fragments of coal shales were found in it. I had heard previously from the Lakhanpur Raja that coal did occur somewhere in the neighbourhood of Tunga, but I had not time to hunt up all the surrounding country.

These Barakars continue up to a point north-west of Lipingi, but there is no trace of coal. Westwards from this, the same rocks were traced to Lachmanganj, their existence under the alluvium there being proved by the debris from a well in the compound of the Raja's shooting lodge.

Barakars are next met with in the Arand, south-east of Kumrewa. They consist chiefly of massive felspathic sandstones and grits often much iron-stained.

In a reach to the east-south-east of Sair, there is a seam consisting of coaly and carbonaceous shale, apparently not containing any good coal. This is the locality marked '*coal-field*' on the old maps.

It is probably the source of the coaly fragments seen in the bed many miles northwards, but cannot possibly be that of the large slabs seen near Tunga. Shaly fragments of coal may, I believe, be carried in rivers for enormous distances; even in the present sluggish state of the river, fragments may often be seen incessantly rolling over and over along the bottom.

[1] J. A. S. B., Vol. XVII, p. 66.

[2] *Op. cit.*, Vol. XXXIV, pt. II, No. 1, p. 24.

[3] Indian Antiquary, 1873, p. 243.

Sandstones, as before mentioned, continue up to the Sair and Kesma ghât; west of the river they extend into the peculiar raviny country beyond Sair.

There the rivers have cut down to a considerable depth; in the massive sandstones producing a perfect maze, very difficult to traverse.

A locality for coal on the Chornai river is marked on the map, but this I did not visit.

I have above alluded to the doubtful character of the sandstones at Kesma.

UPPER SANDSTONES.—West of the Arand valley there are a number of flat-topped and sharply scarped hills, which are evidently formed of sandstones identical with those of the Pilka hills. On the east, too, similar scarped faces show under the trap of the Mainpat. The first locality at which these rocks were actually examined was in the hill east of Kesma. They are coarse grits, presenting no striking contrast in lithological characters to some Barakar rocks. About 3 miles north of Matringa the Talchirs are covered by sandstones, which seem to belong rather to this group than to the Barakars. But they still require much close examination.

In the streams which constitute the head of the Arand, there are fallen masses of trap and laterite which have been brought down from the tops of the hills.

The Matringa ghât is an almost sheer descent of 900 feet into Udepur. At the top of the ghât there is laterite *in situ*, and below it a succession of argillaceous shales, and pink, white, and yellow sandstones, which become somewhat pebbly towards the base. If 600 feet is added for the thickness of the sandstones in the hills above the ghât, then we should have a minimum total of 1,500 feet for the thickness of this group.

Between the foot of the ghât and Amuldih there are some trap dykes, which are probably continuations of some observed in the Kairja valley, near Bakulo, by Mr. W. T. Blanford.

The evidence afforded here of disturbance of the coal-bearing rocks is very strong, there being a difference of level between the Barakars and Talchirs of Sair, &c., and those of Udepur, in the Mand section, of at least 1,000 feet.

That they occupied these relative positions at the time of deposition is most difficult to believe; it seems much more probable that they were once connected, and that the difference of level was produced subsequently, possibly at the period of the outpouring of the Mainpat trap. The discovery of coal measures on the Hazaribagh plateau has already pointed to the probability of the present level of the plateaus as contrasted with that of the surrounding valleys, being at least to some extent due to local upheavals.

The Mand Coal-field.

The connection of the Udepur coal-measure (Barakar) rocks westwards with the great spread which includes the Korba field, has been pointed out by Mr. W. T. Blanford. My observations were confined to the Udepur area, *i.e.*, to the valley of the river Mand, and the areas to the north and east of it.

This is a very irregular shaped area, extending from north to south, for a distance of 35 miles. On the north it is connected by upper (Hingir) sandstones with the Rampur field. On the south and south-east it is bounded by Vindhyan and metamorphic rocks which strike steadily in the direction of Korba. On the east the coal measure rocks are covered by the upper sandstones, and it is uncertain whether the former appear in the valleys beyond the ranges formed of these sandstones. On the north-east, besides the overlapping sandstones, a portion of the boundary is formed of granitic gneiss rocks.

TALCHIRS.—So far as is known at present, the areas of Talchir rocks occurring in this field are of small size. Proceeding from north to south, the first Talchirs encountered with occur detached from the field, in the valley of the Kairja river, north of Rabkob.

In the section north from Mirgurha, granitic gneisses with, for the most part, an E. W. strike, occupy the bed of the river nearly up to the Kumhar road-crossing where Talchirs come in. These, especially the boulder bed, continue up to half way between Bajpar and Bakulo, where there are some hills of yellowish or grey sandstone which seemed to be of Talchir age.

At Rabkob several of the reaches of the Mand river are occupied by Talchirs, blue and grey sandstones and the boulder bed.

North-west of Rabkob, in the valley of the Samasota (or Gopal) river, there is an area of Barakar rocks, showing evidence of extreme disturbance. On the borders of this there are some outcrops of Talchirs, and in the centre of it, at the broken crest of a very remarkable anticlinal, rocks of the same group are exposed.

From this to the south-east corner of the field no Talchirs were seen in the Mand or any of its tributaries. At the south-east corner, Talchirs, resting on granitic gneiss, crop from underneath the Barakars; they are last seen in the Sukia stream, and consist chiefly of shales and sandstones with imperfectly developed boulder bed.

BARAKARS (COAL MEASURES): *Mand River section.*—Passing westwards down the river, from the Talchirs seen near Rabkob, the first Barakars met with occur in the reach east of Saipur. At the north end of it there is a small coal seam, of which the section is as follows :—

Dip 5°, to W. N. W.

Coaly shale, about	8″
Parting...	8″
Coaly shale and coal	1′ 4″
Base hidden.	

Beyond this, there are massive beds of sandstones and grits in some of the reaches; in others, for from 1 to 2 miles, no rocks whatever are exposed. Between this and Khargaon there are two or three outcrops of coal and coaly shale, but no coal. At Khargaon there are two seams, the upper containing carbonaceous shale, and the lower, which is seen under a massive sandstone, contains 1′4″ shaly coal. Half a mile from the mouth of the Saria stream there are several seams containing carbonaceous shale with coaly layers. From this, for 3 miles, there are only a few outcrops of sandstones, several of the reaches being filled with sand. A short distance from the Kopa river there is a seam containing a foot of coaly shale, base not seen. Between the mouths of the Kupa and Khanddhoa there are two seams of grey and carbonaceous shales with a dip of about 10°, to S.

A similar outcrop is seen in the reach west of Hathi. After this, up to a point 1 mile south of Dorki there are only a few outcrops of a peculiar yellowish and grey sandstone, not Talchir, but very unlike typical Barakar.

Under the east bank close by there is a seam of coal shale and poor coal, the latter 15 inches thick. The base of the seam is not exposed. Dip, 5° north-east. After this, there are numerous sandy reaches showing only rare exposures of sandstone.

Below Koraikela, hills consisting of the upper sandstones abut on the river.

From this to the boundary formed by Vindhyans at Daijari, the only rocks seen are sandstones occasionally associated with shales, which latter are in two cases somewhat carbonaceous.

The Vindhyan and gneiss boundary runs with the last reach, and in one place gneiss is exposed in the bed of the river. This boundary did not seem to be faulted. The high ridge of quartzites probably formed the boundary of the Barakars at the time of deposition exactly as it does now.

Tributaries of the Mand.—Above Rabkob fragments of coal were found in the bed of the Mand, which were apparently brought in by some of the small southern tributaries.

Kairja river.—In the Kairja, Barakar rocks extend for about three-fourths of a mile from the mouth. Near the base there is a seam consisting of carbonaceous and coaly shale with thin layers of coal. The boundary appears to be natural: a boulder bed, possibly of Talchir age, rests on gneiss; but there is also some evidence of crushing up and disturbance at the junction.

Samasota river.—At the mouth of the Samasota (or Gopal) stream, north-west of Rabkob, there were abundant fragments of coal, which proved that there was an extension of the Barakars in that direction. The section in fact abounds with coal seams, which at first have a slight rolling dip, but evidence of disturbance soon becomes apparent, and the river gives a section of a fine anticlinal, in which, on the rise, the seams and associated sandstones dip at angles from 40° to 55°, to east. From underneath these, a Talchir boulder bed with associated shales and sandstones crops out, but after one-fourth of a mile or so the Barakars re-appear; but the fall of the anticlinal is less steep than the rise, and the dip is not too great for the working of some of the seams. The following is a list of the seams seen in this river:—

		Ft.	In.
1st.—Fair coal under massive sandstone, dip, 8° north-west . .		1	3
2nd.—Shaly coal—seen		3	.
	Ft.		
3rd.—Shaly coal much weathered	9		
Banked with sand, not exposed	4		
Good bright coal	3		
	——	16	

Base not seen, dip variable, 5°—8° to West-30°-North and North-West.

4th.—In a North-East to South-West reach, not represented on the map.

	Ft.	In		
Coal	3	4		
Grey shale	6			
Coal and carbonaceous shale	1	6		
Grey shale	1			
			11	10

Sandstone.

Dip North-East

5th.—A fine large seam exposed on the southern bank, dip quaquaversal.

Sandstone			20	
Seam—				
1. Shaly coal, about	2			
2. Coal, inferior, but burnable	1	11		
3. Grey shale		10		
4. Flaky coal shales with irregular coaly layers	9			
5. Coal, good, varies	1	6		
6. Grey shale	2	2		
7. Same as 5	5			
			22	5

Base not seen.

Unless there be coal below, I do not think this seam could be worked with any good result. This seam may be the same as No. 3. I think it is, for No. 4 is repeated in the next reach; the thickness slightly altered, but the relative position of the component layers the same. After it, there is a long south to north reach, towards the end of which, before the entrance to an east to west one and then continued in it, there is the following remarkable section, showing an amount of disturbance unparalleled in those portions of the Sirguja coal-fields which have been as yet examined:—

			Ft.	In.
1. Sandstone q. p.			30	
(1) 2. *Seam*, dip 33° East-North-East.—				
	Ft.	In.		
a—Coal, good	1			
b—Shale	3			
c—Carbonaceous shale, with coaly layers	3	10		
d—Coal, about	2			
			9	10
(2) 3. Sandstone, about			50	
4. *Seam*—				
Stony and shaly coal			13	8
5. Sandstone			42	
(3) 6. *Seam*, dip 50°.—				
Coal withc arbonaceous shale parting	4	3		
Covered	9	9		
			14	

			Ft.	In.
7. Sandstone			29	5
(4) 8. *Seam*—				
Coal and coal shale, much hidden			9	9
9. Sandstone			44	5
(5) 10. *Seam*—				
Coal and carbonaceous shale frequent partings, but much of the coal good			34	4
Dip 50° falling to 45°.				
11. Sandstone			39	0
(6) 12. *Seam*—				
Concealed	23			
Flaky coal	7	7		
			30	7
13. Sandstone			51	0
(7) 14. *Seam*—				
Coal and carbonaceous shale portions good			20	7
15. Sandstone			75	0
(8) 16. *Seam*—				
Poor earthy coal and carbonaceous shale seen			4	
17. Sandstone with pebbles, say			50	
TOTAL			517	7

Talchirs, boulder bed, shales and sandstones, in a north-west reach. Barakars come in again after one-fourth of a mile or so. Close to the boundary there is a seam of coal and, in the next reach one with a dip of 35° to N. W., it is 15 to 16 feet thick, and is of very variable quality. In the next reach, E. W., there is an exact repetition of the section on the other side of the Talchirs, but with the dip in the opposite direction, 35°—40° W. and W.-N.-W. changing to north towards the end of the reach.

In the next long north to south reach there is a seam of 4′ 6″ of coaly shale and coal, dip 15° to N.-E. showing a complete change of direction. I am not sure whether this is a repetition of one of the above seams. Another seam is seen in the next reach after which the sandstones again resume their horizontal position, and the same bed may be traced for a considerable distance.

Strong nests of coal occur in some of these sandstones.

A few reaches further, there is a seam at least 10 feet thick, consisting of the same flaky-looking coal.

A short distance beyond the Boro and Jamungri road ghât there is a 5 feet 10 inches seam of stony and shaly coal; the upper half contains fair coal; the dip is low to south-east, but the bedding all about appears to be very irregular.

Another seam in the next reach is seen on the Boro side. It contains about 10 feet of shaly coal, a portion of which has been on fire, though it contains much impurity; a fresh fracture shows a fair proportion of bright layers. Beyond this, there was still evidence of seams occurring in the higher reaches.

Between Tuludha and the Samasota, *viâ* the Jamungri road, there are several outcrops of Talchirs and gneiss, which afford further evidence of the disturbance and disruption of the beds in this neighbourhood, and render it extremely doubtful what the extension of the seams in a western direction may be. Should it ever be required to search for coal here, I would recommend the vicinity of Boro, east round to south at a distance of about half a mile, as the most favourable for making trial borings. The evidence of extensive disturbance of the seams, and consequent difficulty of working them in the country between the Boro hill and the Mand, would render it less desirable to test that area in the first instance.

Meria Kota stream.—In the Meria Kota stream beyond the first tributary, there is a seam of poor coal, of which 6 feet is exposed, dip to north-east. The same seam is again seen further on, where it shows a thickness of about 8 feet.

Some distance beyond two small waterfalls, there is a seam with a dip of 30° north. It is faulted against a bed of sandstone. Close beyond is a seam (possibly the same) with a dip of 8° north-east. It does not contain any continued thickness of good coal, being much parted by shaly layers. This is followed by another seam of about 6 feet with a dip of 10° to east. The coal is for the most part flaky and inferior. At the east to west boundary, west-south-west of Jamungri I saw no traces of coal from the higher parts of the stream, though it is probable that some of the Boro seams may extend thus far eastward. At the same time, it may be that the Barakars are covered up within a short distance of this by the higher sandstones and grits.

In the stream which rises near Jamungri I commenced to examine south-west of the village. Sandstones and grits, apparently Barakars, continue for more than a mile. Then Talchirs from the eastern boundary occupy the bed of the river for a few reaches, after which it runs in a deep gorge, which it has cut for itself in massive sandstones. As represented on the map, this river has the unusual feature, for one in a rocky country, of having two mouths whereby its waters join the Samasota. The explanation is that the narrow gorge being unable to carry off at times the whole of the water, the surplus finds a passage for itself by a northern outlet. I did not see any seam in this stream, but fragments of coal occur. Rolled fragments of gneiss abound, being brought in by the eastern tributary.

Ududha river.—The river south of Ududha (Hudhuda of the map) traverses deep gorges cut in massive sandstones. South-west of the village there is a seam of which the top only is exposed. At the highest point examined, a little north of west of the village there were still fragments of coal brought from higher reaches.

Saria river.—In the Saria river a little beyond the road-crossing, there are two seams of carbonaceous shale with coaly layers.

For several miles sandstones only are seen; they show more tendency to roll than is common in other parts of the area; the prevailing dips are 5°—10° to west and south-west.

North of the village of Konda there is a seam containing a few inches of coal in the exposed part. In an east and west reach higher up the stream there is a seam which, in addition to carbonaceous shale, contains about 3′ 6″ of flaky coal.

A short distance beyond this, there is another badly seen seam containing, apparently, several feet of coal mixed with shale.

At the Baisi and Ambgaon ghât and for some distance up and down stream a nearly horizontal seam paves the bed of the stream; it contains some good coal, but the whole thickness of the seam does not apparently exceed 5 feet. Between this and the Doridih and Ambgaon ghât there are no outcrops visible; but fragments of coal occur brought down from above. South of Potia there are sandstones which are probably Barakars.

Simi river.—About ¼ a mile from the junction there are two seams of coaly shale with much carbonaceous shale, neither of any use. A little further on there is a seam with a dip at first to the west, afterwards changing to 12° south. It contains about 15′ of grey and black shales, and, in one place, a band of rather less than a foot of fair coal. The same seam shows at intervals for a considerable distance. I did not examine beyond the Chithra and Simipali ghât.

Kopa river.—From the mouth up to Chithra the rocks are for the most part covered. Near the mouth of a small stream, which joins the Kopa south-west of Chithra, there are three seams of from 2′—3′ each; they contain coal of fair quality mixed with carbonaceous shale. The dip of the first is 17° to west, but the third rests on a sandstone which is locally tilted to 35° to west.

A short distance beyond the southern tributary, there is a seam of rather more than 3 feet of carbonaceous and grey shales, with some coaly layers towards the base. In the reach entered by the next northern tributary, there is a considerable seam of carbonaceous shales, but no coal. Beyond the Kodardih stream there is a seam of carbonaceous shale 3′ 8″, dipping at 5° to south-south-west, but no coal.

Beyond this up to the Bartapali crossing I saw no seams, the river for the greater portion of the way being in a deep gorge of massive horizontal sandstones.

The last seam but one, mentioned above, is apparently one alluded to by Mr. W. T. Blanford;[1] it rolls a good deal and is of uncertain dip, but I saw no sign of coal in it

Khanddhoa river.—North of Hathi is a seam close to the road; it consists of 18′ of slightly coaly shale with a dip to south of about 8°.

About 2½ miles beyond this there is a seam with about 10″ of coal towards the base, the upper part consisting of grey carbonaceous shales, dip 5° to west. In the interval between these there are massive sandstones and two or three outcrops of carbonaceous shale, but no coal.

Beyond this there are several repetitions of the same seam and several outcrops of carbonaceous shales. At the road crossing between Nouapara and Jogra there is a seam containing less than a foot of inferior coal with a slight rolling dip to south.

Kurja river.—In the stream north of Pori there is a seam containing 1 foot of inferior coal much mixed with shale, dip 3° east. Before it was reached a number of transported slabs of coal with shale, generally 12″ thick, were found

[1] Records, Vol. III, pt. 3, p. 71.

lying in the stream. I can scarcely believe that they were derived from this seam, as they appear to be of much better material than what is seen *in situ*, but I did not see any traces of coal of similar character in two reaches further west, which were the limit of my examination in that direction.

Baghoud river.—From the mouth to the village of Galimar the Baghoud only shows sandstones and shales; some flakes of carbonaceous shale occur, but none *in situ*. The upper part of this river as also of most of the foregoing one traverses the upper or Hingir sandstones.

Bendo river.—In this river there are several outcrops of carbonaceous shale but no coal.

Jhampi river.—In this river the rocks exposed by the section are red, yellow, and white sandstones; no trace of coal or carbonaceous shale. I am inclined to believe that all these belong to the upper group.

Kurket river.—For half a mile from the mouth no rocks are seen; afterwards, towards the top of the first reach, there are coarse sandstones and grits similar to those in the Mand. Beyond this the river exposes Talchirs. The masses of coal seen in the bed are derived from seams in the Raigarh and Hengir field, which are traversed by the higher reaches of the river.

In reference to the economic prospects of this valley, I am distinctly inclined to regard them favourably. While it must be admitted that the majority of the seams which have been examined. as they happened to be exposed, do not disclose coal useful in quantity and quality, it should be remembered that the sections are much covered and the disturbance of the beds (excepting in the few noted instances) has not proved sufficient to give anywhere a complete section of the succession actually existing.

In some cases it is possible to trace the same bed of horizontal sandstone for several miles. The area being in the centre of the basin there is a good prospect of boring proving the existence of valuable seams.

Upper or Hingir Sandstones.

On the northern and for a considerable portion of the eastern boundary, the Barakar rocks are covered up by the upper sandstones. The peculiarities of the Matringa ghât section, alluded to below, afford evidence of great disturbance of level between different portions of the coal-fields. But I must confess myself not prepared at present, with the imperfect data which I possess, to attempt an explanation of the action which has taken place. The difference between the level of the Talchirs of the Arand and of the Samasota, whether produced by flexion, faulting or aboriginal deposition, amounts to from 900—1,000 feet. In all probability, this is really a measure of the subsidence which has taken place.

North-east of Porea there are sandstones with pebbles. These appear to be more common at and near the base of the hills than high up in the sections. The Boro hill and its neighbours are composed of ferruginous sandstones and grits. The scarped range to the east of this is formed of similar rocks, but less ferruginous and more compact. They are split up into angular blocks, in such a manner that at a short distance I supposed them to be metamorphics.

The spur south of Balpeda is composed of sandstones and grits. In the streams near Jamungri there are some sandstones and white argillaceous rocks which may be Barakars; but I rather incline to the belief that they must be included with the upper rocks. The range east of Jamungri is formed of sandstones and grits, south and east of which metamorphic rocks come in and bound the field up to the Sisringa[1] plateau. It is possible that there are sandstones on this plateau; but the first place in which I again met with them was in the Ghoradah hill; from thence the boundary, from various reasons, is very indistinct, but I believe it approximates closely to what is represented on the map, *i.e.*, it runs round the Enderkona hill.

The hill Ghoradah, 2,595 feet or some 1,500 feet from its base, is formed of sandstones and grits capped by laterite. All the hills south from this appear to be of the same sandstone, so that the gneiss boundary must be thrown considerably east of its position near Rabkob.

Whether gneiss or Barakars occupy the valleys, which occur further east of this range of hills, remains to be seen. It is probable that all the hills and ranges marked with distinct scarps are formed of the upper sandstones.

The Enderkona hill is formed principally of a pinkish sandstone, which is scarped similar to those in the hills further north. At Kida the base of the hill is formed of compact purple sandstone. Round the base of Enderkona hill the boundary runs to Aghori, and from thence to the hills below Gumar, which touch the Mand, and are continued again on the western bank.

The river south of Taraikela exposes red and yellow sandstones with occasionally white grits; some of the former contain red jasper pebbles.

The high ground south of Taraikela is formed of ferruginous sandstones, grits and shales, with bands of iron-stone. From thence to Kataipali the boundary of these upper rocks has been roughly traced in that neighbourhood; they lap over on to the Talchirs. Their further eastern extension from this was not traced.

Sufficient has been said above to show how complete the unconformity of these rocks is with respect to the older formations, and yet the difficulty of separating them from the underlying Barakars in some sections is excessive. Taken as a whole, their lithological characters and the absence of coal are such as to justify their abstraction from any close connection; but individual beds often present the very strongest resemblance to certain grits and sandstones of the Barakars. In all these particulars, as well as in their physical characters, they present much similarity to the grits of the Rajmahal hills.

I have often been struck with sections especially round the Mainpât and neighbouring *pâts* as being exact repetitions of some I examined in the Rajmahal hills. Here as there, there are massive distinctly scarped sandstones, which rest indifferently on Talchirs, Barakars or gneiss, and are covered by trap and massive laterite.

Since the above was first written, these upper (Hingir) sandstones have in part been identified by their fossil contents with the Kamthi group, but representatives of higher Gondwana groups are also very possibly present too.

[1] A village close to east-by-north of Chuimati summit.

Vindhyans.

It has been mentioned above that the coal-bearing rocks are cut off on the south by a ridge of rocks of Vindhyan age. These consist of quartzites and quartzitic sandstones.

At intervals granitic gneisses intervene along the boundary.

The quartzites are first met with on the west bank of the Mand, opposite Ero; there they form a succession of high ranges, often with steeply scarped sides. The strike of these hills corresponds with that of the boundary, and indeed of the river itself, for 2 miles. Below Daijari the boundary is suddenly deflected to the east, which direction it maintains for several miles, and then it strikes in the direction of Sambalpur.

The observations hitherto made on the metamorphic rocks are too scattered and detached for special record. It will be an interesting task to trace the origin of the gold which is found in the old alluvial deposits of the tract which extends between the Mand and Ebe rivers. As these deposits lap round a central group of metamorphic rocks, the existence of auriferous quartz reefs in them may very possibly be hereafter proved.

Report on the Pench River coalfield *in Chhindwára District, Central Provinces, by* W. T. BLANFORD, F R.S., *Senior Deputy Superintendent, Geological Survey of India.*[1] (*With a map*)

The coal seams described in the following pages occur at a distance of from 12 to 20 miles north-north-west and north-west of the station of Chhindwára, in the Central Provinces, and in the neighbourhood of the river Pench, a tributary of the Kanhán river and ultimately of the Godávari. The occurrence of coal at one of the localities, Barkoi, has been known for some years. It was first discovered about 1852, and was mentioned by the late Mr. Hislop in a paper published, in 1855, in the Quarterly Journal of the Geological Society of London The country was roughly mapped, both geologically and topographically, by Mr. J. G. Medlicott, of the Geological Survey of India, in 1856, and the tract in which coal seams have now been discovered is shown, in the map,[2] to be formed of the rocks of the Indian coal measures, or Damuda series of the Survey classification. Mr. Medlicott's survey was necessarily merely general, and could not comprise the search for outcrops of coal, a task involving the examination of every stream and nala, of every hill side and every field. The utmost that could be done was to define the area in which such a search could be carried on with a chance of success.

[1] The trial borings in the Shahpur coalfield having proved very unpromising, the prospect of a coal supply in this region turns to the Pench river field, some 85 miles to the east on the same (southern) border of the Sátpura basin of Gondwána rocks. As a good indication of what is to be expected there, Mr. Blanford's report (written 16 years ago) is published in anticipation of the detailed survey to be shortly undertaken. The line of localities marked on the annexed map sufficiently indicates the position of the coal measures.

[2] Memoirs of the Geological Survey of India, Vol. II, part 2.

In the present instance there seems to have been unusual unwillingness or apathy on the part of the natives of the district, who alone could effectually search for outcrops of coal seams, in furnishing information of their existence. Officer after officer has been compelled to report his inability to ascertain the existence of any other coal in the district than the Barkoi seam, and it was ultimately by accident that Major Ashburner, the present[1] Deputy Commissioner of Chhindwára, became acquainted with the occurrence of the mineral at Sirgori, and following up the discovery most energetically, succeeded, in the short space of three months, in ascertaining its presence in the several places mentioned below.

I am happy to report that I have been able to form a highly favourable opinion of the coal and of the facilities for working it which are presented by its mode of occurrence.

Before proceeding to describe the several outcrops in detail, it may be useful to mention briefly the peculiar topographical and geological characteristics of the tract in which they occur. Upon the former depends the facility or difficulty of communication with adjoining districts, and upon the latter the existence and area of the coal field.

Physical geography of Chhindwára District.

To the north of the Chhindwára district lies the flat open valley of the Narbada, to the south are the broad plains of Nágpur, watered by the tributaries of the Godávari; these areas are approximately at the same level, about 1,000 feet above the sea. They are separated by a tract of much higher country averaging at least 2,500 feet and being part of a belt which may be considered to stretch nearly across India dividing, in the west, the watershed of the Narbada from that of the Tapti; in Central India, intervening between the Narbada and the feeders of the Godávari; and to the east, separating the valleys of the Son and other affluents of the Ganges, from the tributaries of the Mahánadi and other rivers of Orissa. In the country between the Narbada and the Wainganga, this belt is about 80 miles broad, the northern portion consisting of massive flat-topped hills, intersected by deep ravines, all covered by dense jungle traversed by very few roads, and very thinly populated. The southern portion, which is the true dividing ridge, is far less irregular, and in most parts consists of a broad undulating table-land, generally fertile, and, in many places, well populated and cultivated. Upon this southern portion are the Civil Stations of Betúl and Chhindwára.

Distribution of coal-bearing rocks.

Although a very considerable proportion of this belt of country in the Betúl, Chhindwára, and Narsinghpur Districts consists of coal measure rocks (Damuda), these are chiefly found in the deep valleys and on the sides of the hills of the wilder northern portion. Such is the case at Mopáni, on the Sitariva, near Narsinghpur, and in the several known coal localities of the Táwa valley. So far as the country has been hitherto mapped, the only coal measure rocks known to occur upon the table-land forming the southern portion of the belt are those in the neighbourhood of the Pench river, in which the seams now discovered occur. This

[1] That is, in 1866.

circumstance is of great importance, because communication with the country, either north or south, involves only the descent of one scarp, while from all the other known coal-fields of the neighbourhood of the Narbada, communication with the south involves an ascent of from 1,000 to 1,500 feet, in addition to the descent of the southern scarp. The distance of the various coal localities from Chhindwára is from 12 to 20 miles; from Chhindwára to the foot of the ghât at Rámakona is 28 miles, and from Rámakona to Nágpur 50, total 90 to 98 miles.

General geological structure of Pench river coal-field and neighbourhood.

The general geological features of the neighbourhood of the Pench river coal-field may be mostly gathered from Mr. Medlicott's map. The following brief description is derived chiefly from the map, partly from my own observations. The country north of the station of Chhindwára consists of metamorphic rocks, which extend to the west far beyond the town of Umrait, and continue for about 10 miles due north of Chhindwára, when the sandstones and shales of the Damuda series are brought in by a fault of unknown dimensions, but undoubtedly of considerable magnitude; probably, north of Chhindwára, of some thousands of feet. Upon both formations indifferently is a great spread of horizontally or nearly horizontally bedded trap, which covers the whole country further east, but, to the west, has generally been cut through by river valleys, and denuded, so as to expose the subjacent formations; caps and patches of the trap remaining here and there. To the north of Umrait, between that town and the villages of Barkoi, Butaria, &c., a patch of trap covers a considerable tract, concealing the boundary between the metamorphic rocks and the Damudas, and trap again overlaps the boundary north-east of Chhindwára. From a few miles north of the Pench again all is trap. The country in that direction rises into a great table-land, in parts as much as 3,500 feet high.

The base of the trap is extremely irregular: the beds have been poured out upon an irregularly denuded and uneven surface of metamorphic and sedimentary rocks, and masses of the igneous rocks, filling up previously existing hollows in the older formations, occur even at the lowest portions of the country now exposed. Thus trap occurs in the bed of the Pench river in two places, one north, the other south of the villages of Chenda and Digawáni. Trap dykes intersect the sedimentary and metamorphic rocks in places, but they do not appear to be very numerous, nor to affect the quality of the coal.

Besides the Damuda or coal measure sandstones and shales, I found a considerable portion of the Pench valley to be occupied by rocks of a very different mineralogical character, thick beds of deep red clay with interstratifications of coarse sand and sandstone, and bands of nodular limestone. These do not appear to contain coal, and their appearance strongly recalls that of some beds, which I described in 1860 as the Panchet series,[1] and which overlie the coal-bearing rocks

[1] It should not be forgotten that this paper was written 16 years ago before Mr. H. B. Medlicott had classified the Gondwána beds of the Sátpura region and before anything definite was known of the Godávari Gondwánas. The only areas of these rocks that had been properly surveyed were those of the Damuda valley. The supposed Panchets doubtless belong to a much lower horizon and are in all probability Motur.

of the Raniganj field. But my time was too limited to allow me to investigate this intricate question, and my attention was necessarily chiefly confined to the coal beds.

Villages referred to, marked on map.

On the accompanying map (an extract from sheet No. 4 of the Revenue Survey of the Chhindwára District) will be found the various villages referred to below as in the neighbourhood of the coal outcrops. The majority of them are also marked upon the map, already referred to, as published to accompany Mr. Medlicott's report on the central portion of the Narbada district. These villages extend in a line running nearly due east and west for a distance of about 16 miles.

In describing the localities in detail, I shall commence with those farthest to the east, and proceed regularly westwards.

I. Sirgori seam.—The most eastwardly locality in which coal has as yet been discovered is close to the village of Sirgori, and nearly a mile north of the Pench river. The coal was found in a well sunk, twelve years ago, by the malguzar or patel of the village; and this circumstance coming accidentally to the knowledge of Major Ashburner, led to the discovery not only of this seam, but of all the others between Sirgori and Barkoi. Major Ashburner sank a shaft by the side of the well, and at the depth of 28 feet came upon the coal. All the beds cut through were of sandstone, coarse or fine; and the roof of the coal consists of coarse sandstone, obliquely laminated. After cutting into the coal more than 3 feet, water came in rather rapidly, and the shaft was stopped. With some little difficulty from the influx of water, I succeeded in digging into the coal further, until I had reached 4 feet 9 inches from the top of the seam. How much thicker it may be, I cannot say. The whole is of good quality, perfectly uniform, without shale partings.

Thickness of seam.

Quality of the coal.

The coal burns excellently, and leaves a considerable quantity of perfectly white ash. The most remarkable point about this coal is its freedom from iron pyrites. I have never seen any Indian coal which appeared so little impregnated. This is a most valuable property—the absence of pyrites tends to ensure the coal from decomposition on exposure to the weather, and from liability to spontaneous combustion; and if sulphur be not present in some other form, it especially qualifies the coal for the manufacture of iron and for forge purposes.

Geological character of neighbourhood and probable extent of seam.

The well in which the coal was found is just south of the larger of the two collections of houses composing the village of Sirgori. These two portions of the village are about a quarter of a mile apart, the larger being north-east of the other. In a nala between them fine sandstones are exposed, dipping north about 5°; these may be traced beneath the north-east portion of the village, and re-appear on the low hills about 200 yards east of the well; dipping at that spot north-north-west, at the same angle as before. The beds thus appear to be continuous along their outcrop for a distance of nearly half a mile, and unless some break of the rocks occur in the ground between their outcrop and the well, (of which I could trace no indication,) the coal should be continuous beneath them throughout that distance at least; how much further it is difficult to say. This is along the strike of the beds east and west. Coming up the dip of the beds towards the south, sandstones and shaly beds are seen with the same north dip in two or three places, the ground being however covered thickly with surface soil, so that very little can be seen. No trace of any outcrop can be found, and in a well 22 feet deep, just south-east of the smaller or south-west portion of the village, no coal was found, nor yet in another well, about 200 yards further west. Yet, if the coal continued at the same dip, its outcrop should be either at these wells or a little south of them, and in either case some indication of the coal should be seen in them. Its absence induces me to believe that the coal is, in all probability, cut off by a fault; and there is an indication of such a fault in a small nulla, 200 or 250 yards south-east of the shaft in which the coal is seen. This fault brings coarse grits against shaly sandstone, and it appears to have an east and west direction (perhaps east-north-east to west-south-west, a common direction of the faults in this country). The amount and the direction of its throw are quite uncertain, scarcely any rocks, except the overlying trap, being seen in the neighbourhood to the south. Boring is very desirable about this to test the extent of the coal, which, if the fault be a downthrow to the south of no great amount, would be found on the south side of the fault within a depth not too great to prevent its being worked. If the fault be an upthrow to the south, the coal will of course be cut out in that direction.

A small stream runs in a valley north of Sirgori village (the larger portion), and then passes east of the village, and runs southward, passing a little east of the shaft. In this stream, east of the village, and about 200 yards north-north-east of the shaft, sandstone is seen overlying shale,—the latter very carbonaceous in parts, dipping about 3° to north-north-west, and containing fossil plants. The sandstone differs greatly from the much coarser beds immediately overlying the coal. It is necessary to mention this, as the dark shales may be easily mistaken for an outcrop of coal, and it might be thought that the seam is here brought to the surface and repeated by a fault. I can see no indication of such an occurrence, but every reason, on the contrary, for believing that the coal underlies all these rocks.

Going further north, the beds appear to dip regularly until about 200 yards north of the village, and a quarter of a mile from the shaft where there may possibly be a fault. It is not very clearly seen, nor can even a guess be hazarded as to its amount or the direction of its throw; indeed, it is not certain that anything more than a sharp bend in the rocks exists, and of course it is quite possible, and even probable, that the coal recurs beyond.

It will thus be seen that for at least half a mile along the strike, and for nearly as great a distance along the dip, there is every probability that this seam is continuous; and it is in the highest degree probable that the coal will be traced far beyond these limits if proper boring operations are carried out. Before attempting to work the coal, a few preliminary borings should be made, especially in the direction of

Necessity for boring, and spots where it is desirable.

the dip, that is, north and south of the well in which coal has been found. These borings are needed both to ascertain, more definitely than can be done by surface exploration, the extent of the coal seam, and also to prove whether its thickness be constant,—seams of which the roof consists of coarse sandstone, as in the present case, being sometimes variable in thickness. I would point out as one place for a boring the spot immediately south of the large banyan tree, which is itself south of the north-east portion of the village, in order to ascertain if the coal approaches the surface there. Another boring should be made 150 or 200 yards north of the well in the low ground east of the village.

It is also extremely desirable that the coal should be at once sunk through in the shaft, and its thickness ascertained. This might be done at small expense.

Summary of prospects of the locality for coal-mining.

It has, I think, been clearly ascertained that the coal at this place is sufficiently thick to be profitably worked, that its quality is good—in some respects exceptionally so—that the dip is low and highly favourable, and that there is every probability that the seam is continuous over a sufficiently large tract of ground to repay considerable outlay in starting a colliery.

II. Sirgori seam No. 2.—Up the little stream, already mentioned as running north of the village of Sirgori, beyond the spot where indications of a fault are seen, nothing except coarse sandstone is met with, the dip of which is doubtful. About half a mile west-north-west of the village, the outcrop of a second seam of coal is seen in the nala, dipping north. On the north bank of the nala, Major Ashburner sank a shaft to a depth of 18 feet, passing through the seam, which was 3 feet in thickness. The shaft passed entirely through shale and shaly sandstone. The coal was mostly extracted in large slabs, and these, after being exposed on the surface for three months in the dry season, have split up into papery layers, to so great an extent as to prove that the coal is ill suited for carriage to any distance, and very liable to decompose. It is also rather shaly and impure; and, considering that the thickness of the seam is only 3 feet, I do not think it could be profitably mined. The coal burns well, leaving a grey ash, and appears tolerably free from pyrites.

There is not, so far as I can see, the smallest reason for supposing this seam to be a repetition of that seen to the south; the beds do not roll up again, and the two coals differ essentially in thickness, mineral character, and in the nature of the overlying rocks.

Some shales seen in the nala, just above this spot, are so ferruginous that they might be used as an iron ore. The ferruginous portion does not, however, appear to be of any great thickness; all that was seen was a band a few inches thick and somewhat variable in the proportion of iron contained.

III. Chenda seam.—The next locality to the westward is in the bed of the Pench river, 4 miles west of Singori, and half way between the villages of Chenda and Digawáni. The river here runs from north to south. So large a quantity of the mineral is here exposed in the bed of the river, that it is rather remarkable that its occurrence should not have been before noticed; and it shows clearly the utter indifference of the natives of the country to the subject, since they must have known that coal was worked at Burkoi, only 10 miles away, and sufficient power of inductive reasoning may be supposed to exist, even in the minds of Gonds, to enable them to see that the two minerals are identical. The spot was shown by a *gwála* to Major Ashburner, after that officer had offered a reward for the discovery of coal elsewhere than at Barkoi or Sirgori.

The spot is just north of the ford in the Pench, on the road between the villages of Chenda and Digawáni. About half a mile to the south, trap comes in, both in the river bed and on its banks: to the south of the trap, near the village of Dala, metamorphic rocks occur. North of the trap, for a considerable distance, no rocks are seen; at the ford the deep red clays and white sands, to which I have already referred, and which I believe to belong to a higher series of beds than those associated with the coal, are seen dipping about 20°, to south 10° west. They are faulted against the Damudas, or coal measure beds close by, and, about 100 yards north of the fault, coal appears on the east or left bank of the river.

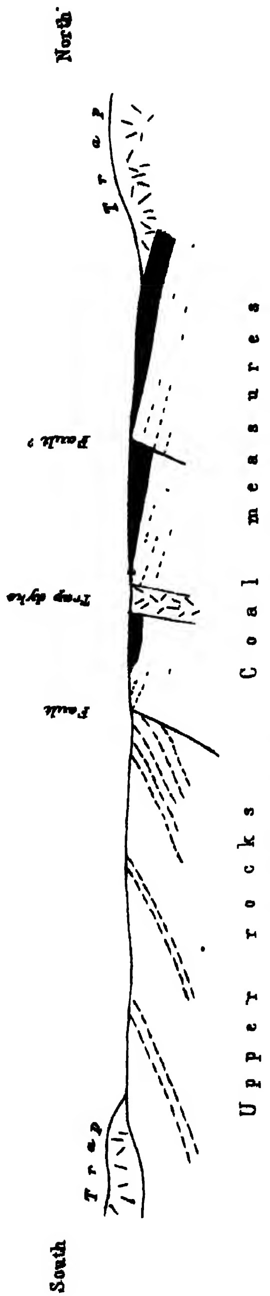
Section of seam and thickness of coal.

At this spot, Major Ashburner has made a small cut into the coal to ascertain its thickness; this cut exposes the following section:—

	Ft.	In.	Ft.	In.
Shale, decomposed, about			3	0
Coal ditto	1	0		
Shale	1	3		
Coal, rather shaly in places, but generally of fair quality	7	0		
Shale, in parts very carbonaceous and containing layers of good coal	2	0		
Coal of good quality	4	3		
			15	6

of which 12 feet 3 inches consists of coal.

Immediately to the north, a trap dyke, running east and west, and about 30 yards broad, crosses the seam. This great mass of igneous rock has tilted up the seam slightly to the north, but does not appear to have much affected the coal. The seam re-appears just north of the dyke, dipping north, at first at an angle of about 10°, but, immediately beyond, at a much lower dip, varying from about 3° to 5°. For about 150 yards from the dyke, the outcrop of the coal seam occupies the bed of the river; then massive sandstone comes in, apparently brought up by a small fault, striking nearly east and west, with an upthrow of about 20 feet to the north. The sandstones dip to north-10°-east at about 5°, and, upon them, about 30 yards further the coal seam re-appears; that is to say, coal of great thickness comes in, and it has every appearance of being the same seam. If not, two very thick seams must here occur, one above the other, and separated by only a few feet. The coal seam continues to crop out in the bed of the river for a short distance, when it is covered by the overlying trap, which forms both the bed of the stream and the hills on its banks. This trap continues for a considerable distance up the river.



Sketch section to illustrate mode of occurrence of the Chenda coal seam.

The accompanying sketch section will serve to show the manner in which this coal seam is exposed in the Pench.

On the east bank of the river is a rich alluvial and highly cultivated plain, in which no rocks are seen, until hills of trap rise close to the village of Chenda, half a mile away. To the west, the coal is seen in a small nala, about 150 yards from the bank of the river. The spot I believe to be north of the small fault mentioned, as repeating the seam in the river. I could not trace the seam further west, nearly all the rocks being concealed by surface deposits.

Quality of coal.

The quality of the coal is fair throughout; the lower 4 feet 8 inches seam, especially, being of very good coal, brighter and purer even than that of Sirgori, but containing much more pyrites. It burns with rather less flame than the Sirgori coal, and leaves a grey ash, reddish in parts. The smaller quantity of flame is, doubtless due to the Chenda coal being taken from nearer the surface, and partly perhaps to the vicinity of the large trap dyke to the place from which the coal was taken.

Mining prospects of the locality.

Whether this coal can be mined profitably or not, depends upon its continuance to the north under the overlying trap, and this continuance can only be ascertained by mining or boring. Very possibly the trap is of small thickness, and in that case the coal should be found beneath, but the base of the trap is too irregular for any opinion to be formed of its thickness from surface examination.

In any case, however, an enormous quantity of fuel could be quarried from this spot, for quarries could be made along three lines, as far as the outcrop of the coal extends—

1st.—South of the trap dyke.

2nd.—North of the trap dyke, and south of the fault.

3rd.—North of the fault.

No quarries, however, should be made along the third line, especially in the neighbourhood of the river, if deep mining to the north be found practicable. A large proportion of the coal would, of course, be inferior and chiefly suited for local purposes, but the lower portion of the seam would probably be sufficiently good for railway locomotives, and would bear carriage to a distance.

Taking the whole circumstances into consideration, it does not appear to me that this locality is so promising as Sirgori. At the Pench there is probably a thicker seam of coal—indeed the thickest as yet known to exist in Central India; the quality is good, and the dips are highly favourable, but the rocks appear to be much cut up by faults and trap dykes. If the coal is to be mined, it will be beneath very hard trap, entailing some expense in boring and shaft sinking, and the quantity of water met with is likely to be large. But if the coal does continue beneath the trap, its quality will assuredly be far better than in the section now exposed, (provided only that some sandstones or shales intervene between it and the trap, which is probable,) and it will be well worth the expense of a few borings to ascertain this. The spots for boring would be in the bed of the river, 150 or 200 yards north of the place where the coal disappear beneath the trap, and at the base of the hills to the east and west of the same spot.

Locality for borings to prove continuation of coal.

IV. Harrai seam.—At the village of Harrai, 2 miles south-west of Digawáni, coal was found in a well sunk for irrigation. After draining the well of water, however, we found that mud had accumulated to so great an extent in the bottom as to conceal the coal. There would have been considerable delay in clearing this. I cannot, therefore, state the prospects of this seam. The spot is close to the continuation of the large fault already noticed in the Pench, which brings down the red clays and their associated sands and limestones in the same manner at Harrai as further east.

V. Ráwanwára seam.—About a mile north of the last, and half mile south-west of the village of Ráwanwára, the following section is exposed in a nala:—

	Ft.	In.	Ft	In.
Shaly sandstone			4	0
Fine compact sandstone			2	6
Coal	1	0		
Sandstone, shaly in parts	1	3		
Carbonaceous shale and coal	0	4		
Sandstone, with streaks of coal	0	7		
Carbonaceous shale and coal	0	6		
Dark grey carbonaceous sandstone	0	4		
Carbonaceous shale	0	8		
Coal	2	4		
			7	0
Carbonaceous shale			0	6
Grey shale (bottom not seen)			2	0
TOTAL			16	0

Here there are only 3 feet 4 inches of workable coal, divided into two parts by 3 feet 8 inches of sandstone and carbonaceous shale with threads of coal in places.

The dip at the outcrop is about 7° to the north. To the south there appears to be faulting, and the underlying rocks are not seen. On the west, coarse sandstone dips at 15° to north-10°-east, while to the north-east sandstones, overlying the coal, are seen nearly horizontal.

The coal appears to be of fair quality, but has not been cut into. A small quantity, dug from the outcrop, burned well, almost without flame, and left a grey ash. The seam, however, appears too thin to be worth working, especially in the neighbourhood of other and much thicker beds.

VI. Ráwanwára seam, No. 2.—About a mile west of Ráwanwára, coal again crops out in a nala; the precise thickness is not seen. At one spot there is only 1 foot of coal with shale above and below; dip 10°, to north-20°-west; 30 or 40 yards further west, 3 feet of coal is exposed, divided into two parts by about 2 feet of shale; and a few yards further, 2 feet of coal are seen, all dipping in the same manner as in the first instance mentioned. The two latter may belong to the same seam, the top not being seen in the latter case, and neither top nor bottom in the former. The whole section is very ill seen in a narrow nala, and a small shaft on its north bank would be necessary to prove the thickness of the coal seam, its quality, &c. So far as I could judge, the seam did not appear to be of any great thickness.

VII. Parassia seam.—The next place examined was about three-fourths of a mile west-south-west of the village of Parassia. Outcrops, apparently of the same seam, are seen in three places within a few yards of each other. No clear section is exposed. The coal dips to the north, and appears to be about 5 feet thick, but it is so crushed and decomposed that nothing can be clearly made out. The top of the seam is not seen, and the thickness may exceed that above mentioned; there is much appearance of faulting. On the whole the conditions are not promising, but without a small shaft or boring on the north side of the nala, nothing can be determined with certainty.

VIII. Bhandaria seam.—Rather more than a mile south-west of Parassia, and on the boundary of the village lands of Parassia and Bhandaria, several small seams of coal are seen in the Gogra nala, dipping about 10° to north-10°-west; the dip becoming more westwardly down the nala, which runs towards the east. The section is rather difficult to measure exactly, being somewhat broken. It appeared to be the following:—

	Ft.	In.	Ft.	In.
1. Coarse shaly sandstone			many feet.	
2. Shale, top not seen			2	0
3. *Coal*	1	0		
4. Sandstone of various colours, yellow, red, and black	1	8		
5. *Coal*, very good (the base is concealed by gravel, and the thickness may be a few inches more, but only a few inches)	2	6		
6. Sandstone	3	6		
7. Carbonaceous shale	0	8		
8. Sandstone	0	9		

	Ft.	In.	Ft.	In.
9. Carbonaceous shale	0	7		
10. Coal, very good	3	3		
11. Shale	0	6		
12. Sandstone	0	3		
13. *Coal*	0	6	15	2
14. Shale	...		0	2
TOTAL			17	4

Or the coal seam, from the top of No. 3 to the bottom of No. 13, measures 15 feet 2 inches, of which 7 feet 3 inches is coal, in general of excellent quality. Just below this a turn in the nala brings in the thickest seam, No. 10, again, and its thickness is correctly seen in a vertical bank: it then consists of—

		Ft.	In.
No. 9	Shale		
10	*Coal*	1	0
	Shale	0	2
	Coal	3	6
	TOTAL	4	8

The difference (1 foot 5 inches) in the two measurements may be due to error in measuring a broken, ill-exposed seam in a nala in the first instance, or to the seam having thickened in the interval, about 30 yards; the latter, I think, the more probable, as seams like this, much interstratified with beds of sandstone, are generally somewhat irregular in thickness, and often excessively so. Indeed the whole section recalls the irregular beds of the western portion of the Raniganj coal-field in several respects.

Thirty or forty yards down the stream, the outcrops of two other small seams are seen, but neither exceeds 18 inches in thickness. They are beneath the above section, 15 to 20 feet of sandstone and shales intervening. Ascending the nala, also, to the east, and 20 to 30 feet above the section measured, a thin, very shaly seam is met with.

Mining prospects of the locality.

Whether this locality is workable or not, depends mainly upon the constancy or otherwise of the seams in thickness, which must be determined by boring or by driving galleries on the seam. The coal appears excellent; the dips, though higher than in some other localities, are not unfavourable; but there is the important drawback, that with the good coal a considerable mass, equal to the coal in bulk, of useless rock intervening between the seams must be dug out, which would much increase the cost of working the coal.

IX. Bhutaria seam.—Close to the boundary between the village lands of Bhutaria and Bhandaria, about a mile west of the former, and barely half a mile east of the latter, is the next locality where coal has been found. The seam dips to the southward or to south-east at about 5°. The outcrop is obscure. I dug out the top of the seam, but under 1 feet 4 inches of splendid coal I found a thick bed of shale, very hard and difficult to cut. After sinking into this for 1 foot 10 inches, I tried another spot, a few yards further east, where the coal re-appeared in the nala, though the top was not seen. Here I sank a small hole to a depth of 4 feet 6 inches, without reaching the bottom of the coal. Including, therefore, the abovementioned seam of 1 foot 4 inches, there is, at this spot, a minimum thickness of nearly 6 feet of coal. It is of fair quality, and burns well; but the lower portion contains a great quantity of iron pyrites, and even the upper 1 foot 4 inches, when burnt, leaves a reddish ash. This, however, appears to be the only drawback. Very little can be made out in the adjoining ground, but the dip is low and favourable.

About a quarter of a mile to the east in the same nala, the top of an outcrop perhaps of the same seam can be traced for at least 100 yards.

X. Barkoi seam.—The next spot to the west is Barkoi. Here alone have any workings taken place, and even here they have not been extensive, consisting of one small quarry. The opening made, however, is sufficient to enable a better judgment of the characters of the seam to be formed than in most of the other places mentioned.

The coal was first observed on the banks of a nala which runs from north-east to south-west, just south of the northern portion of Barkoi village. The quarry is north of the nala, and exposes the following section:—

	Ft.	In.	Ft.	In.
Earth			0	6
Sandstone			3	3
Shale (generally decomposed)			6	9
Coal, decomposed in the quarry, shaly towards the top	2	4		
Shale, variable, about	0	2		
Coal	6	0	8	6
Shale becoming sandy below.				
			19	0

The total thickness of coal is thus 8 feet 4 inches, but the uppermost 1 foot or 18 inches and the bottom 1 foot are very shaly, and there appeared to be about 6 feet of good coal. In the quarry as at present worked, there is less than this, for the upper portion is too much decomposed to be of much value, and not more than from 4 to 5 feet of marketable coal is obtained. None of the coal quarried can, of course, be equal in quality to that which would be obtained if it were mined from a greater depth below the surface. The dip is to the south-south-west, and does not appear to average more than 3°, though amounting to as much as 5° in places.

Associated rocks and geological characters of neighbourhood. Probable extent of seam.

On the south side of the nala, massive felspathic sandstones overlie the coal. They can be traced to a considerable distance, and are well seen in another small nala to the south, which cuts deeply into them. To the north, the coal doubtless crops out close by and is lost. There is no indication of its recurrence in this direction, though the beds roll and are unsteady in their dip.

To the west, or rather south-west, down the little nala, the coal can be traced for a short distance, and about 150 yards below the quarry, north-west, Mr. Adams, the agent in charge, sank a small pit at my suggestion, and came upon coal at the depth of 7 feet; this gives a fall of about 20 feet in 150 yards; but as the direction of the nala is not quite the same as the dip of the coal, the latter being more to the south, the inclination is in reality rather greater. To the east and north-east, the coal can be traced for some distance. About 150 yards from the quarry, there is a small fault with a throw of, apparently, not more than 15 or 20 feet, striking north-west—south-east, which brings down the coal to the north-east. At least such appears to be the case, though the seam beyond is immediately covered by sandstone instead of by shale. This may be due to the decomposition of the shales in the nala bank, and to the sandstone sinking on the coal, or to local unconformity at the period of formation of the coal—a very frequent occurrence in coal measures. At the same time the seam may be different. The section thence to the east is ill seen; the nala is small and choked with blocks of sandstone; but about 200 yards beyond the fault the coal re-appears, perhaps brought up by another little break.

In a nala which passes by the southern portion of the village of Barkoi, south-east of the coal outcrop, a poor section of the beds is seen, the greater portion consisting of coarse felspathic sandstone, similar to that overlying the coal. One small outcrop of a coal seam, 6 inches thick, is met with. The beds have no distinct dip; they are, apparently, slightly inclined to the south. There is no reason for supposing the small outcrop to be in any way connected with the Burkoi seam. In all probability it is much higher in the series, and the Barkoi seam, if constant, which there appears no reason to doubt, should underlie all these beds. In fact, there seems every probability of its existing under a considerable tract of country.

Quality of coal.

The quality of the Barkoi coal is much the same as that of the others described. It is less bright than the Chenda coal, but it is undoubtedly fair fuel. It, however, contains a large proportion of iron-pyrites, more than any of the other seams, except perhaps that of Bhutaria (and this has not been sufficiently cut into to determine). The lower portion of the seam appears, however, to contain less pyrites than the upper. In the coal now extracted from near the surface, the pyrites has, in great measure, decomposed, leaving the joints of the coal lined with peroxide of iron, and a white efflorescence (? sulphate of alumina) frequently forms on the surface. Both of these tend much to injure its appearance. The coal ignites with great readiness, and burns very freely with much flame. The ash is in parts deep red, in others only reddish, and in some cases nearly white.

Despite the considerable proportion of pyrites contained, this coal does not appear to decompose rapidly when exposed. In some heaps, which have been lying on the surface exposed to the weather for two years, the coal has not split up or broken to any extent.

Mining prospects.

The workings hitherto, as I have stated, have been but small. The circumstances under which the seam occurs are, I am inclined to believe, very favourable for mining; the dip is low, and although faults occur, they appear to be of small amount. The shale and overlying massive sandstone would form a good roof in all probability. There is nearly a mile of gently rising ground between the outcrop of the coal and the hills to the south, so that, if the seam be continuous, a colliery may be worked for many years before it is likely to be necessary to sink shafts to any great depth. In this, as in all collieries, however, some preliminary exploration by boring is desirable before any large outlay in shaft sinking and erection of steam engines is undertaken.

Any coal that may exist to the north of the nala may as well be quarried as the quarries there would not affect deeper workings. South of the nala quarries would be objectionable, as if deeper workings are commenced, the quarries will tend to increase the quantity of water met with.

IX. Gogri or Hingladevi seam.—The last place that I visited to the westward was about 2 miles west of Barkoi, in the lands of the village of Gogri, and close to a small jungle shrine known as Hingladevi. Mr. Adams showed me the spot, and, at my request, set workmen to dig into it. They had reached the depth of 4 feet 10 inches from the top of the coal seam, when I saw the spot a second time, all the thickness being through coal. The excavation was continued, and beneath 9 inches of shale was found 6 inches more of coal, beneath which shale recurred, and below that again sandstone. I was informed of this in a letter from Mr. Adams, accompanied by specimens, which reached me after I had left the coal-field. I do not quite understand whether the upper portion of the seam exceeded 4 feet 10 inches or not; but there must be a seam of above 5 feet of coal. It apparently dips at a low angle to the south.

The coal appears of fair quality, though shaly in parts. The outcrop is in the bed of a small nala running between low hills, but with ranges of greater height to the south and south-east. In consequence of the unevenness of the ground, the spot is not so well suited for mining as Burkoi.

Coal at Paláchaori.

Besides all the above localities, coal is said to have been found in a well at the village of Paláchaori, north of the last described locality.[1]

Importance of the discoveries of coal seams.

The above details will, I think, serve to show that these discoveries of coal seams are the most important that have been made in India for many years, amongst all the previously known coal localities in Central India; to the west of the meridian of Jabalpur, there are but two seams, both at Mopáni, in Narsinghpur district, which exceed 4 feet in thickness. Near the Pench, within an area of 16 miles in length from east to west, no less than six (or, including Bhandaria, seven) localities have now been discovered in which seams exceeding that thickness occur; and when it is borne in mind that, with two exceptions only (Barkoi and Hingladevi), the whole of these localities have been discovered since the month of October last, and solely through the researches of Major Ashburner, I think it is only reasonable to believe that many other workable seams may still remain undiscovered in this

[1] Since my departure, Major Ashburner informs me that he has discovered two other places where coal occurs.

neighbourhood, and that there is every probability that this portion of the great Sátpura coal-field equals, in mineral wealth, the coal-fields of the Damuda valley in Bengal.

Favorable conditions for mining.

The circumstances under which the coal occurs, appear, in most instances, to be favorable to mining enterprise. The dips are very low, and, so far as a judgment can be formed from the very imperfect sections exposed at the surface, there appears good reason to anticipate that both the quality and thickness of most of the seams will be found constant, at all events over a considerable area. Faults are numerous, but the majority do not appear to be of sufficient amount to affect mining operations injuriously. It is probable that these faults will be found to decrease in number, the greater the distance from the fault bounding the coal measures to the south.

Quality of coal.

The quality of the coal, so far as a judgment can be formed by inspection, and by burning it in heaps, is similar to that of the coals of Raniganj, and other mines in that neighbourhood. It is a free-burning, non-caking coal. It is decidedly inferior to the better qualities of English coal, both on account of the larger proportion of ash and of the lower percentage of fixed carbon. At the same time, I see no reason for doubting that, for railway purposes, the Pench river coal is perfectly adequate; it is just as well suited as the Raniganj coal, with which the East Indian Railway was worked for some hundreds of miles, and I believe that for all local purposes, or for fuel for stationary steam engines, it is excellently adapted; while for the manufacture of iron, the freedom from pyrites possessed by the Sirgori seam, if found to be constant, should give that coal advantages over most other Indian coals with which I am acquainted.

Seams discovered probably distinct.

The question may possibly arise, whether some or all of the seams discovered may not be identical. Without a much closer examination of the country than it has been possible to make hitherto, it would be impossible to answer this question precisely in every instance; and, even were an exact survey made, the large area of ground covered and concealed by trap, and other formations more recent than the coal-bearing rocks, would render the tracing of each seam a hopeless task, until mining operations had advanced considerably. But there can, I think be no question that the majority of the seams are quite distinct from each other, and I have not been able, in a single instance, satisfactorily to ascertain that any seam examined was identical with one seen elsewhere.

Localities best suited for mining.

Amongst the localities I have described above, I am disposed to believe that those best suited for mining purposes are Sirgori, Bhutaria, and Barkoi; but further explorations by boring, as I have shown above, are desirable in every instance. The availability of the splendid seam on the Pench, at Chenda, depends, as I have above stated, on its continuance to the north, beneath the trap in the river. Further exploration is required at Parassia, and it is extremely desirable that the thickness of the seams there and at Bhutaria, and, above all, at Sirgori, should be ascertained at once.

Specimens sent for analysis.

With this report I send for analysis fair specimens of the four principal seams named, *viz.*, Sirgori, Chenda, Bhutaria, and Barkoi[1]; those from Chenda being taken from the lower 4 feet 3 inches coal, which is the best part of the seam, and which in the cutting made was least injured by surface decomposition. The specimens from Barkoi are also from the lower part of the seam, for the same reason. In comparing the results it should be borne in mind that the coal from Chenda, Bhutaria, and Barkoi, is outcrop coal, and that fuel of a superior description will, doubtless, be obtained, by mining—fuel, however, which may probably contain more sulphur and gaseous ingredients, while the coal from Sirgori is mined from 30 feet below the surface. It should also be remembered that the present specimens are small fragments, broken from various parts of the seam, for the purpose of obtaining a *fair sample* of the whole.

Climate of district.

Apart from geological conditions, the circumstances of the country are, I think, favorable for the establishment of collieries,—the country being high, the climate is cool, and well suited for Europeans, except for two or three months, during which, owing to the prevalence of jungle, it is feverish.

Supply of labour.

The population of the district is chiefly Gond. These people are indisposed to work regularly, and labour for hire may have to be imported. But *quasi*-aboriginal tribes like the Gonds, if kindly treated, are excellent labourers, and are likely to become good miners, being superior in physique to the average labourers of Central India. The miners at Raniganj belong exclusively to races allied to the Gonds, Bhonris, Santals, &c.

The immediate neighbourhood of the Pench river is fertile, and the villages are numerous; away from its banks, the population is sparse, and the greater portion of the country covered with jungle.

Camp, Betul district,
March 10th, 1866.

	Fixed Carbon.	Volatile matter.	Ash.
[1] Chenda	61	16	23
Barkoi	50·3	26	23·7
Bhutaria	49·3	26·5	24·2
Sirgori	61·6	28	10·4

List of coal seams hitherto discovered in the Pench river coal-field.

Number.	Name of Village.	Thickness of seam.	Thickness of good coal in seam.	Average angle of dip.	Direction of dip.	Remarks.
		Ft. In.	Ft. In.			
I	Singori	Above 4 9	Above 4 9	5°	N.	Not yet sunk through.
II	Ditto	3 0	3 0	5°	N.	Not workable.
III	Chenda and Digawáni (Pench R.)	15 6	12 3	3°	N.	
IV	Harrai	?	?	?	?	Particulars not ascertained.
V	Rawanwára	7 0	3 4	4°	N.	Probably not workable.
VI	Ditto	?	Above 3 0	10°	N. 20° W.	Thickness not ascertained.
VII	Parassia	?	Above 5 0	?	N.	Exact dip and thickness not ascertained.
VIII	Bhandaria	15 2	7 3	10°	N. 10° W.	
IX	Bhutaria	Above 7 8	Above 5 10	5°	S.	Total thickness not sunk through.
X	Barkei	8 6	About 6 0	8°	SSW.	
XI	Gogri (Hingladevi)	? 6 0	? 5 3	About 5°	S.	This seam may be a few inches thicker.

Note on borings *for* coal *at* Engsein, *British Burma*:[1]
By R. ROMANIS, D.Sc., F.G.S.E.

A company being engaged in exploring the post-tertiary strata at Engsein, about 6 miles from Rangoon, for coal, I took the opportunity to examine the specimens brought up.

The surface consists of sand loosely cemented together by peroxide of iron. Throughout this bed there are found nodules and bands of a hydrated peroxide of iron containing manganese. This bed of yellow-sand passes into a bed of grey sand, evidently the same before the iron in it has become peroxidized.

Below the sand is a considerable depth of a fine clay, like pipe-clay. From this one or two fragments of stone were brought up, which, I am informed, are called "boulders" by the borers.

I was puzzled to account for their presence. They are composed of a crystalline rock of comparatively small density; with a glass I observed small reddish-brown crystals like garnet. There are no traces of volcanic action in the neighbourhood so far as I know, and it is not easy to see how they could have been brought into their position. They may have been shot from some former sub-marine volcano now concealed beneath the alluvium of the delta, or they may be fragments of a meteorite. I have not yet analysed them.[2] In this bed, too, were found casts of the roots of some plant, apparently a water-lily. A thin seam of lignite, about an inch in thickness, was passed through. I shall take an early opportunity of re-visiting the borings.

I understand that a friable sandstone underlies the clay, and that this crops up to the surface at a short distance to the north, and that a new boring is about to be commenced to explore the strata below.

On Sapphires *recently discovered in the* North-West Himalaya:
by F. R. MALLET, F.G.S., *Geological Survey of India.*

Some excitement has been caused of late in Upper India by the discovery, in the region beyond the snows, of stones concerning which the most conflicting accounts have appeared from time to time. At first they were described as amethyst, or as blue quartz, subsequently as sapphire, and later on as amethyst and as sapphire again.

An equal amount of uncertainty has prevailed as to the locality from which the stones have been obtained. The discoverers, naturally enough, have not

[1] Frequent mention having lately appeared in the newspapers of a discovery of coal near Rangoon, some information on the subject would naturally be expected from the Geological Survey I had endeavoured, officially and otherwise, to ascertain the locality of the exploration and the facts upon which it was based, but without success; so the notice (communicated unsolicited) by Dr. Romanis is very welcome. I need hardly add that it only increases our curiosity as to what can have led to the search for coal in such ground.—H. B. MEDLICOTT.

[2] In a later note Dr. Romanis adds—"I have analysed the so-called boulder and satisfied myself that it is not of igneous origin, but there must be some mistake in the account I received of the way it was found."

felt particularly eager to impart their secret to the rest of the world, and have perhaps not displayed any remarkable energy in correcting such false reports as may have arisen. There appears, however, to be little doubt, now, that they are found in the neighbourhood of Padam in the Zánskár District, within the territory of Káshmir. The discovery seems to have been due to a landslip, which laid bare a new face of rock in which some of the blue stones were visible. On working into the rock large quantities were subsequently extracted. The first lots of the mineral that were brought across the snow are said to have been sold at extremely low rates, owing to the ignorance of the carriers as to their value. Now, however, the gems are fetching high prices, Rs. 85 a tolah, having, it is said, been offered at Simla, while for individual specimens considerably higher rates have been declined. It was stated some time ago that the Delhi jewellers had bought up more than two lakhs (20,000£) worth of the stones.

As it was desirable that the real nature of the mineral should be ascertained beyond doubt, two specimens, obtained at Simla, were recently forwarded to this office by direction of the Punjab Government: one of these weighs about 250 grains, the other about 110. The larger is in part transparent, and of a rich blue tint, partly bluish-white and translucent. The smaller is almost wholly of the transparent blue variety, but shades into brown in one or two spots. The physical and chemical characters of the specimens show conclusively that they are true sapphire. The specific gravity of the larger piece was found to be 3·959 and of the smaller 3·961.[1] The mineral scratches topaz; is infusible before the blow-pipe; and when fused in powder with acid potassium sulphate, and dissolved in water, yields a bulky precipitate of alumina with ammonia.

Of two other specimens, subsequently sent, which were obtained by the Assistant Commissioner of Kulu, one is a double hexagonal pyramid (probably 4P2, but with irregular angles) terminated by the basal planes. There are four or five smaller crystals of sapphire attached to, or embedded in, it. The crystal is 2¾ inches long and weighs rather more than 800 grains. It is bluish-white and translucent, with transparent blue portions irregularly mixed. The other specimen is about an inch and a quarter long and seven-eighths of an inch diameter at one end. It constitutes one-half of a double hexagonal pyramid (2P2), which has been broken across near the centre. The fracture displays a cavity of considerable size in the interior, containing two crystals of tourmaline. One of these is of comparatively large size, but showing no well-defined faces; dark-brown in colour, and semi-transparent. The other is very much smaller, but well-crystallised (∞P2. ∞R. R.), and transparent, the body of the crystal being light brown, and the termination indigo-blue.

I have also had an opportunity of examining a consignment of the gems

[1] The specimens are thinly coated in places by a white mineral (with minute botryoidal surface), which may be gibbsite, but there is too little of it for satisfactory determination; and on the surface of the larger one there are two or three minute crystals of greenish tourmaline. The presence of these minerals introduces a slight error into the above-given specific gravities, for the sapphire alone. This error, however, probably does not exceed 1 in the second place of decimals, and reduces the apparent below the true value. Although the amount of foreign matter on the smaller specimen is much less than on the other, the observed specific gravity is higher by only ·002.

aggregating some pounds in weight. They included, besides irregular fragments, a considerable number of crystals, one of the largest and best formed of which was a double hexagonal pyramid terminated by the basal planes (4P2, 0P.). It measured $3'' \times 1\frac{5}{8}'' \times 1\frac{1}{2}''$, and, like all the others, was bluish-white and translucent, with transparent blue portions irregularly mixed. The blue parts of course constitute the valuable portion of the crystals, and are carefully cut out by the lapidaries, while the bluish-white are scarcely entitled to the name of sapphire, and would be more appropriately designated as corundum. A considerable proportion of the specimens contained small crystals of dark-brown tourmaline, which seem to be most common in the interior and near the centre of the sapphire crystals.[1]

[1] Since the above was in print, the following letter has been received from the Revd. A. W. Heyde, the Moravian Missionary for many years resident in Lahul, than whom no one is more likely to receive correct information on the subject :—

Letter from the REVD. A. W. HEYDE, *Moravian Missionary, dated Kyélang* (viâ *Kangra and Kulu*), *Punjâb, the 18th April 1882.*

Owing to the fact of my being shut up by snow during the winter months, a letter from Mr. Lydekker, of the 21st of February, reached me only four days back. He writes for information regarding the blue stones which have lately been found in the neighbourhood of Lahul and sold in large quantities, chiefly by Lahulies, at Delhi and elsewhere. I have gathered what information I could.

The place from which all the blue stones which have come into the market *till now* have been taken, is, according to one informant in Padar [Padam], about half a day's journey from the top of the *Umasi Pass*, 2 or 3 kos *to the east* of the village of Machél (which I cannot find on my maps). According to another informant, the place is reached best from the top of the Pentse La, between Zánskár and Rangdum. From the Pentse La you have to cross the same range which is crossed by the Umasi, when you find the spot on the *southern* slope, after having descended for a short distance. This way is only known to the Zánskár people living near the Pentse La. The exact spot is situated as high as the line of perpetual snow where vegetation has ceased. Its surface is a dark-brown earth, followed by a stratum of a white stuff, resembling, as my informant said, *bul* (soda), which is found in the Nubra valley.

In this white stratum regular crystals or shapeless bits, large and small, of the blue stone are found singly and can be taken out "like potatoes" without any instrument. But when this white layer, which does not appear to be thick, is worked through, more or less solid rock is met, which is *also blue*, and from which bits can be taken only with instruments. This information I received from different people, two of whom professed to have seen the place. How far all this may be true, I cannot tell, though I have no reason to doubt the information as a whole.

Very interesting is the statement made to me, that this place is not the only one where these stones are found under similar conditions. In the immediate neighbourhood of the spot described, the people know of two others, in one of which the blue stone is found not below the ground but in horizontal seams of a large rock, but also, as it appears, surrounded or embedded in the white stuff. Another spot where this stone is said to exist is from 50 to 100 miles or more to the east, or rather south-east, in the *same range*, above the monastery of Bardan in Zánskár (a village near by is called Pipsha). And only yesterday I heard that a shepherd of Lahul *thinks* he has seen the same stone here in Lahul high up in the hills on the right side of the Chandra Bhaga, about two marches upwards from Tri Lok Náth; in this case, also, it seems, at the height of the snow line. This, if true, would not be in the main range, but in a branch of it. In Padar these stones were first found, as is said, by a *shikári* about two years ago. Only last year he and other people of Padar found out that they had some value, beginning to sell them to traders and several people of Lahul, at one rupee a seer. As yet the Maharája's people know only of that one place where the stones are found, the whereabouts kept secret by the people for fear of [illegible] which might follow a disclosure. As the stones are found at so great a height, partly in well nigh inaccessible spots, the Maharája's guards who have been stationed to watch that one place from a distance are unable to prevent the inhabitants from taking out and selling stones still. In Zánskár large quantities of them are still in the hands of the people, amongst which there are said to be some very perfect and large crystals—one of them is said to be a foot in length.

I myself have not made an object of buying such stones, but have seen different bits of them. The upper end of what seemed to have been a regular crystal, having been broken, had two broad sides and *four* small sides. Several shapeless bits were covered with a whitish crust consisting as it were of minute quartz or lime crystals, the crust adhering very firmly. Others were irregularly covered with well-formed small crystals.

The thick end of another broken larger crystal looked for about an inch like topaz, the colour being that of a deep-coloured sherry wine, quite transparent, the two colours (blue and yellow) running gradually into each other.

I forgot to mention that in the localities in Padar where the stone is found, the common pebble in large and small crystals abounds.

Jewel merchants from the plains pay here at present as much as Rs 30 for one tola of the blue stone if the colour is pure. I further forgot to mention a report, according to which also stones of a *red* colour have been found in the same localities.

Notice of a recent Eruption *from one of the* Mud Volcanoes *in* Cheduba.

The following letter from the Commissioner of Arakán to the Government of Burma, relating to a fiery eruption from one of the mud volcanoes in Cheduba, is published in continuation of similar records[1] :—

From Colonel E. B. Sladen, *Commissioner of Arakán, to the Secretary to the Chief Commissioner, British Burma, Rangoon. Dated Akyab, 4th January 1883.*

I have the honour to report a rather interesting phenomenon in connection with the shock of earthquake which was felt at this station on Saturday morning last, the 31st December.

2. The vibrations commenced at about 7-55 A.M., and were continued at intervals from ten to fifteen minutes.

They were not severe, but doors and windows of houses rattled; furniture was made to undergo a see-saw movement, and pendulum clocks in some instances stopped.

3. I was myself at the time on board the S. S. *Mahratta*, off the mouth of the Sandoway river, and the point of interest in relation to the earthquake is, that, simultaneous as regards time with its occurrence at Akyab, we were eye-witnesses of one of those violent volcanic eruptions which have already been observed to take place on some of the islands lying off this coast during the great earthquakes of 1833 and 1839.[2]

4. In the present instance, the eruption occurred in one of the extinct volcanoes near the southern extremity of Cheduba Island.

As we were lying at anchor at the time off the mouth of the Sandoway river, we must have been about 30 miles from the scene of the volcano; but even at this distance a dense column of smoke and broad massive flames of fire were seen to rise, as it were, from the horizon, and stretched far up into the distant sky.

Viewed even by daylight, the sight was a magnificent and impressive one, owing to the great volume of flame and the immense height to which it rose. Dr. McClelland, writing of

[1] Vols. XI, p. 188; XII, 70; XIII, 206; XIV, 196.
[2] Vol. XI, pp. 197, 205.

the eruption in 1833, says that the flames issued to the height of *several hundred feet*; and the description given in Silliman's Journal of a similar eruption in 1839 is to the effect that "fire mingled with smoke and ashes rose to a *fearful height*."

5. In these two instances the observers were within 3 or 4 miles of the eruptions. In the present instance, we were 33 miles in a straight line from the scene of the eruption, and at that distance, the flames, as seen by us, appeared at times to reach half-way up from the horizon to the sky, and to have a lateral (apparent) breadth of from 30 to 40 feet.

They continued to issue forth with greater or less effect for about 15 minutes, and then suddenly disappeared; but the smoke, which had risen in a long straight column, formed itself into a vast black canopy, which hung like a cloud in the sky, and was visible for hours after the eruption was at an end.

6. I may mention that the high land of Cheduba was quite visible from where we were, and that bearings, taken at the time, indicated the scene of the eruption to be the extinct volcano known locally as the "Naga Dwen."

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Donors.

A collection of vertebrate fossils from Perim Island (see above, p. 104).

CAPTAIN. SEARLE,
Supdt. of Marine, Calcutta.

Mammalian bones from pleistocene beds of the Jamna valley, in the Bánda district.

MR. JOHN COCKBURN.

A slab of shale with plant-impressions from the Karharbari coal-field.

W. G. OLPHERTS, C.E.

Two blocks of English patent fuel.

THE MADRAS RAILWAY CO.

A block of cupriferous gneissose schist from the Báraganda copper mine, Hazáribágh.

MR. N. KENNY.

Specimens of crude asphalt, 'boiled pitch,' and 'glance pitch', from Trinadad.

DR. O. F. BEICHMANN.

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MOURLON, MICHEL.—Géologie de la Belgique. Vols. I—II (1880-81), 8vo., Berlin.

RENAULT, M. B.—Cours de Botanique Fossile, Année II (1882), 8vo., Paris.

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Annales des Mines, 7th Series, Vol. XX, livr. 6 (1881), 8vo., Paris.

Annales des Sciences Géologiques, Vol. XII, No. 1, and XIII (1881), 8vo., Paris.

Annales des Sciences Naturelles, 6th Series, Zoologie et Paléontologie Vol. XI, Nos. 5-6, and XII, Nos. 1-2; and Botanique, Vol. XII, No. 1 (1881), 8vo., Paris.

Annals and Magazine of Natural History, 5th Series, Vol. IX, Nos. 49-51 (1882), 8vo., London.

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Beiblätter zu den Annalen der Physik und Chemie, Band V No. 12, and VI, Nos. 1—2, (1881-82), 8vo., Leipzig.

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Bibliothèque Universelle et Revue Suisse, 3me. Période, Tome XII, Nos. 34—36 (1881), 8vo., Lausanne.

Botanisches Centralblatt, Band VIII, Nos. 8 and 10—12, and IX, Nos. 1—6 (1881-82), 8vo., Cassel.

Chemical News Vol. XLIV, Nos. 1151—1153, and XLV, Nos. 1154—1162 (1881-82), 4to., London.

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Das Ausland, Jahrg. LIV, Nos. 50—52, and LV, Nos. 1—9, (1881-82), 4to., Stuttgart.

Geological Magazine, New Series, Decade II, Vol. IX, Nos. 1—3 (1882), 8vo., London.

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April 6th, 1882.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1882. [August.

Note on the coal *of* Mach (Much) *in the Bolan pass, and of* Sharág *or* Sharigh *on the Harnai route between* Sibi *and* Quetta, *by* W. T. BLANFORD, F.R.S., *Senior Deputy Superintendent, Geological Survey of India.*

When on the way, in October 1881, to examine the hill tracts north of Sind and west of the Punjab, I received instructions to examine two localities at which coal had been found, one on each of the routes between Sibi[1] and Quetta. One of these localities, that at Mach on the Bolan route, had already been visited and described[2] by Mr. Griesbach, but after his examination fresh discoveries were made. As will be seen however, my conclusions as to the value of the coal seams are practically the same as Mr. Griesbach's. The other locality, Sharág or Sharigh on the Harnai route, along which it was at one time proposed to lay a railway to Quetta, and which lies to the eastward of the Bolan pass, had not previously, so far as I am aware, been geologically examined.

My visit to both localities was necessarily very brief, but still I think sufficient to enable me to judge of the probability of their affording fuel on a large scale. My opinion, I regret to say, is unfavourable.

It is unnecessary here to enter at any length into the geology of the beds[3]. Mr. Griesbach has already shown, quite correctly I believe, that the coal of Mach belongs to the lower part of the eocene system. The position of the Sharág beds is not so clear[4], but that they belong to the same system is unquestionable. The similarity in mineral character of the beds associated with the coal[5] in both localities is so great that there is probably very little, if any, difference in age;

[1] The terminus at present of the railway.

[2] Report on the geology of the section between the Bolan pass in Biluchistan and Girishk in Southern Afghanistan, Mem. Geol. Surv. India, Vol. XVIII, Pt. 1, p. 22.

[3] I hope to be able to give a fuller account of the geology of the country in a future report.

[4] I had not time to examine fully the surrounding country.

[5] It may be possibly questioned whether the mineral found at Mach and Sharág should be called lignite or coal, but as the latter term has been generally used, I shall retain it. The substance is certainly not a typical lignite.

but the occurrence of coal or lignite beds in the eocene deposits of Western India appears to be local and occasional, and it is not as yet ascertained that all such deposits are on the same horizon.

It will be well briefly to describe each locality separately, and to commence with Mach.

Mach (Much).—The camp known as Mach, between Sir-i-Bolán and Ab-i-gúm, is four marches (about 45 miles) from Quetta, and six marches (about 65 miles) from Sibi. The elevation above the sea-level is nearly 4,000 feet. Hills occur to the eastward and westward, but for about 2 miles east of the camp, and for a much longer distance to the northward, the surface is nearly a plain, much covered by deposits of gravel, and intersected by deep ravines, in some of which sections of the rocks associated with the coal are seen. A particularly good section is exposed in a stream bed running from the north to join the main Bolan river just opposite the Mach camp. This stream is the Maki Nadi of the map, and is, I think, that called the Mach river by Mr. Griesbach, on the bank of which he measured the sections given in detail in his report[1]. Here several beds of coal occur, but very few, if any, of them exceed a foot in thickness at the outcrop[2].

The beds associated with the coal consist of grey and olive shales, weathering into clay at the surface, sandstones mostly very soft, and a few harder calcareous beds, containing marine (or perhaps estuarine) fossils, chiefly bivalve shells (*Lamellibranchiata*) in great abundance, but not of many species. The sections already mentioned in Mr. Griesbach's report afford a general idea of the rocks.

All the beds are greatly disturbed, and in places irregularly contorted, and the dips are, as a rule, very high, and frequently nearly or quite vertical.

Precisely opposite to the camp at Mach, in the bank of the main or Bolan stream-bed, a thicker seam was found[3] after Mr. Griesbach's visit. Into the outcrop of this seam, at the base of the bank, some holes had been made, from two of which, only a very few feet apart, coal was being dug at the time of my visit. The thickness of the seam exposed was 2 feet 8 inches in one hole, 2 feet 4 inches in the other, as nearly as could be ascertained under the circumstances, the holes being small and irregular, no good face of the coal exposed, and a considerable quantity of water running in from the gravel in the stream bed. But of the thickness named, the uppermost, 6 to 8 inches, was very shaly and impure[4];

[1] *Op. cit.*, pp. 23, 24.

[2] Many of the seams are excessively decomposed at the outcrop, and would perhaps prove rather thicker if cut into.

[3] By Captain Johnson, Commissary of Ordnance. This officer had unfortunately left Mach before I arrived, and I found no officer stationed at the post.

[4] The following is an analysis by Mr. Mallet:—

Moisture	7·0
Volatile matter (exclusive of moisture)	38·8
Fixed carbon	17·6
Ash	36·6
	100·0

whilst the lower, 2 feet or rather less, were of better quality. An analysis of a fair sample by Mr. F. R. Mallet gives—

	Per cent.
Moisture[1]	10·9
Volatile matter (exclusive of moisture)	33·1
Fixed carbon	41·0
Ash	15·0
	100·0

The ash is red, indicating the presence of iron pyrites in the coal.

The seam, where cut into, dips about 50° to the north. Ten or 12 feet above it is another much thinner bed, and 12 feet higher another, consisting of several bands of coal, measuring in the aggregate perhaps 20 inches, distributed through 4 to 5 feet of shale. None of the separate bands of coal exceeds 6 inches in thickness. Several other thin seams occur higher in the section.

There is much reason to suspect that the thickness of the principal seam is not uniform. It appears to vary in the few feet exposed, and so far as could be learned from the native workmen, who had been engaged in digging coal from it, it thins out to the westward. The associated clays can be traced for some distance, but no distinct outcrop of the thick seam is exposed. In the opposite direction to the east and north-east, all outcrops are concealed by the gravel in the bed of the stream.

Sharág or *Sharigh.*—The camp and military post marked as Sharág on the map, but commonly known as Sharigh, lies at a distance of four long marches (about 70 miles) from Quetta, and of five marches (about 80 miles) from Sibi, at approximately the same elevation (4,000 feet) above the sea as Mach, in the middle of a plain extending to a great distance to the north-west and south-east, and broader than usual, being probably 7 or 8 miles from north to south, at the spot selected for the camp.

The principal place where coal occurs[2] is about 3 miles south of the post and close to the hills forming the southern boundary of the plain. A small stream, the Siah Dad, running from the plain, cuts its way through the hills to the southward, and close to the spot where it enters the hills a much smaller stream runs in from the west, and exposes in its bed an excellent section of the rocks, which are imperfectly seen in the Siah Dad itself. As already mentioned, these rocks are similar in character to those of Mach,—soft grey or olive shales, more or less sandy, and weathering into sandy clays at the surface, soft sandstones and hard calcareous bands containing fossils. All are vertical or nearly so. In a measured section of about 370 feet of these strata, there are about thirty beds of coal, the great majority less than 6 inches thick, and many only 1 or 2 inches. Only four beds equal or exceed a foot in thickness, and of these, two are chiefly composed of shales. The thickest seam measures 1 foot 9 inches. Fair samples

[1] Water that is driven off at a temperature of 230° Fahr.

[2] I was more fortunate at Sharág than at Mach, for at the former Major Newport, of the 24th Bombay Native Infantry, the discoverer of the coal, still commanded the post when I visited it. He took me over the ground and gave me all the information in his power.

of this seam (No. 1), the quality of which is superior to that of most of the others, and of a thinner band 8 inches thick (No. 2), have been analysed by Mr. F. R. Mallet with the following result:—

	No. 1.	No. 2.
Moisture	6·8	3·0
Volatile matter (exclusive of moisture)	40·8	42·8
Fixed carbon	47·6	46·1
Ash	4·8	8·1
	100·	100·0

No. 1 does not cake, and yields a red ash; No. 2 cakes to a light porous coke, and yields a red ash.

In another spot, three quarters of a mile further north, and consequently nearer to the camp at Sharág, the outcrops of several thin coal seams are seen in the banks of a stream bed. The coal-bearing rocks are probably the same as those to the south, repeated by a roll of the strata. Again, the dip is nearly vertical. One bed of coal was seen a foot thick, and of good quality. It was possible to trace the outcrop of this seam on the surface of the ground for about 350 yards by the aid of a conspicuous band of highly fossiliferous sandstone abounding in bivalve shells, and occurring just above the coal. Within the distance named, the thickness of the coal seam diminished, until it was only represented by a layer or two, scarcely an inch thick, in carbonaceous shale. This was the only instance in which the outcrop of a coal-bed could be traced more than a few yards, and it affords strong presumption of the inconstancy in thickness of these seams,—an inconstancy which has been observed in similar deposits amongst the eocene rocks of other parts of India and Burma.

The country around Sharág has been searched in all directions by Major Newport without any other outcrops having been found. But about 7 miles east-south-east of Sharág, on the road to Harnai, three little seams are exposed 200 or 300 yards north of the road in a small stream running from the north. One of the seams is 7 inches thick, the others 1 to 2 inches. A little further on the Harnai road, a thin coaly layer is seen by the road side. Again, on the same road, about 3 miles east-south-east of a small village called Nasuk, and 12 miles from Sharág, in a section cut by a small stream close to the road, and on the north side of it, four little seams are seen,—the two upper mere layers, the third 8 inches thick, and the fourth, separated by 5 inches of clay from the third, 3 inches in thickness. In all these cases the beds are nearly horizontal. These outcrops, all observed in the course of a single march along the road, render it highly probable that many more would be discovered if a thorough exploration of the country were undertaken; but at the same time they do not add to the probability of thicker beds of coal being found.

The details given above lead to the following conclusions:—

1. Not a single seam has been discovered, either at Mach or Sharág, thick enough to pay for mining on a large scale, even if the thickness of the seam were known to be constant, and if other circumstances were favourable to mining,—neither being the case.

2. The evidence is very imperfect, but so far as it extends, it appears probable that the seams are inconstant in thickness, and thin out within short distances.

3. The conditions under which the seams occur at Mach and Sharág are unfavourable to mining, though not such as to render it impracticable. In the first place, the beds dip at high angles and are often vertical. There is, however, much probability that by search other localities might be found where the dips are moderate, as in the case of the little seams noticed between Harnai and Sharág. Secondly, the associated rocks are so soft that mining would involve the necessity of heavy timbering or of masonry to protect the means of access to the mine.

4. The analyses given above, and especially those of the Sharág coals, show that the mineral found would be of considerable value, if it could be procured in sufficient quantity. It should be remembered that the specimens analysed are taken from the outcrop, and that at a little depth below the surface the quality of the coal would in all probability be better.

A railway could be worked with such fuel, although the work done would be less than that yielded by coal containing a larger proportion of fixed carbon. The quantity of iron pyrites in the different seams is probably variable, but in those especially examined, it does not seem sufficient to prevent the coal being used for a railway.

It is evident that a considerable quantity of useful fuel for local purposes can be procured from the outcrops of the seams. So far, however, as can be judged from the facts hitherto known, the supply obtainable is insufficient for a large work such as a railway.

New faces *observed on* Crystals *of* Stilbite *from the* Western Ghâts, Bombay; *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

During the construction of the Great Indian Peninsular Railway, when very heavy cuttings and tunnels were being driven through the trappean rocks of the Bhor and Thul Ghâts, magnificent specimens of zeolites were brought to light in great profusion. The species occurring most abundantly were stilbite, apophyllite, heulandite, and scolecite, all of which were represented by splendid crystallizations[1]. Large collections were made at the time by Mr. W. T. Blanford for the Geological Museum, where the finest specimens are now included in the systematic collection of minerals.

Most, if not all, of the stilbite specimens fall under one or other of four types[2] :—

1*st*.—Salmon-coloured crystals, generally of considerable size—very commonly, for instance, an inch, and sometimes two inches across (in the direction $\infty \breve{P} \infty$). They have the faces $\infty \breve{P} \infty$. $\infty \bar{P} \infty$. P., and are not uncommonly somewhat (but not highly) sheaf-like, from the aggregation of simple crystals into compound ones. They are generally (but not always) implanted by one end, and hence usually present only one pyramidal termination. Crystals of this type are frequently thickly grouped, occurring either alone, or with apophyl-

[1] Manual of the Geology of India, p. 304.

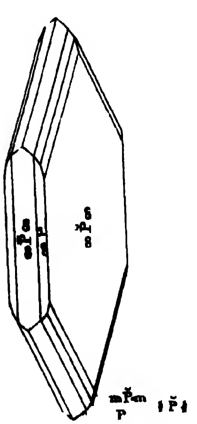
[2] Excluding lamellar specimens, in which the crystallization is obscure.

lite, which not uncommonly takes the form of minute crystals implanted on the surface of the stilbite. Quartz, &c., is also found in the same association, but not so frequently. In other cases the stilbite occurs in isolated crystals of the type in question, being then very usually associated with large, thickly grouped, crystals of apophyllite.

2nd.—Highly sheaf-like forms, sometimes so much so that viewed on the face ∞ P̄ ∞ they have the appearance of a fan, or in the comparatively rare cases where both ends of the crystal are free, of two fans with the points together: the crystals are commonly of considerable size, averaging say one-half to one inch across. They are generally thickly grouped, but sometimes occur singly. They occur either alone, or associated with heulandite, apophyllite, scolecite, or with crystals of the third type.

3rd.—Thin tabular crystals of comparatively small size (more commonly a quarter to an eighth of an inch across, sometimes much less); non-sheaf-like, or very slightly sheaf-like in form, and exhibiting the combinations ∞ P̆ ∞. ∞ P̄ ∞. P. and ∞ P̆ ∞. ∞ P̄ ∞. ∞ P. P. They occur alone, and with apophyllite, heulandite, scolecite, and perhaps other minerals. In one case small crystals of this kind were observed implanted on large ones of the first type, showing that the former were of later formation. The crystals of the second and third types are white.

The crystals of the fourth kind, which are by far the least common, occur on the surfaces of cavities which are lined by minute crystals of quartz. No other zeolites are associated with them (except in one specimen which includes apophyllite). They are salmon-coloured; of considerable size, averaging say half an inch across; generally tabular and non-sheaf-like, or very slightly sheaf-like in form. Generally they present the faces ∞ P̆ ∞. ∞ P̄ ∞. ∞ P. P., but in some there is also a face replacing the edge between ∞ P̆ ∞ and P. The parallelism of the edges between this face and ∞ P̆ ∞. & P., respectively, shows that the formula for the face in question is m P̆ m. Striæ and irregularities on ∞ P̆ ∞. and P. prevent more than roughly approximate angular measurements. For m P̆ m ∧ P. the value 152°¼ was obtained. A more reliable result, however, can be deduced from the observation that the plane angles formed by the edge between m P̆ m. & ∞ P. with the edges between m P̆ m. & ∞ P̆ ∞. and m P̆ m. & P. (all of which edges are straight and sharply defined) are either right angles or extremely close approximations thereto. Assuming them to be actually right angles the calculated value of m P̆ m ∧ P. is 154° 35′, giving a value for m of 2·5098, or a close approximation to $\frac{5}{2}$. Taking m at $\frac{5}{2}$, the value of the angle m P̆ m. ∧ P. is 154° 41, the plane angles formed by the edge between m P̆ m. & ∞ P. with the edges between m P̆ m. & ∞ P̆ ∞. and m P̆ m. & P., respectively, being 90° 8′ and 89° 52′.



The value of the following angles therefore are—

$\frac{5}{2}$ P̆ $\frac{5}{2}$. ∧ P.=154° 41′.
$\frac{5}{2}$ P̆ $\frac{5}{2}$. ∧ ∞ P̆ ∞.=145° 41′.

On one crystal there is also a face m P̆ m replacing the edge between $\frac{5}{2}$ P̆ $\frac{5}{2}$ and ∞ P̆ ∞. The value of m is much greater than $\frac{5}{2}$, but owing to the position of the crystal in a cavity, it is impossible to get even a rough measurement of the angles between m P̆ m and the adjacent faces, without destroying the specimen.

Professor Heddle has noticed the occurrence of a face replacing the edge between ∞ P̆ ∞. and P. on crystals of stilbite from Dumbartonshire, and from near Mount Nombi in Australia. He obtained the value 149° 45′ to 150° for the angle m P̆ m. ∧ ∞ P̆ ∞. in the Scotch specimens, and 152° 32′ to 153° in the Australian. These results, however, he considered little better approximations, and he felt little doubt that the face was the same in the specimens from both localities[1]. The angles 149° 45′ and 153 respectively give a value for m of 2·9266 and 3·3497, the angle when m equals 3 being 150° 22′. The probability therefore would seem to be that the face noticed by Professor Heddle is different from that on the Indian specimens.

The total number of faces, which, as far as I have been able to ascertain, have hitherto been noticed on stilbite, are, ∞ P̆ ∞. ∞ P̄ ∞. ∞ P. P. 0 P., which are given in all mineralogical works; $\frac{3}{2}$ P̆ ∞. noticed by Des Cloizeaux on crystals from Bergen Hill (New Jersey)[2]; m P̆ m (3 P̆ 3?) recorded by Heddle; $\frac{5}{2}$ P̆ $\frac{5}{2}$ and m P̆ m (m having a high value) on crystals from the Western Ghâts.

On the traps *of* Darang *and* Mandi *in the North-West Himalayas,—By Colonel* C. A. McMAHON, F.G.S. (*with two plates*).

The occurrence of intrusive traps in the lower Himalayas is mentioned at pages 21 and 70, Vol. III, Memoirs, Geological Survey, and at pages lvii and 606, Manual of the Geology of India, whilst notices of the trappean rocks of Darang (Drang) and Mandi will be found at pages 58, 59, and 61 of Vol. III Pt. 2 of the Memoirs.

Doubts have at different times been expressed regarding the origin and nature of the traps described in this paper. At one time there was a tendency to regard them as metamorphic rocks; and although in the passages referred to they are spoken of as 'traps,' and are described as occurring along a definite horizon, they do not appear to have hitherto been recognised as true lavas. The microscope, I think, enables us to set any doubts upon this point at rest.

I have examined 26 slices[3] of the trap, of which the ridge to the east of Darang is composed, and 9 slices of the trap, in the same line of strike, exposed in the bed of the Suketi at Mandi.

[1] Mineralogical Magazine, Vol. IV, p. 44.

[2] Manuel de Minéralogie, Tome I, p. 416.

[3] Prepared for me by Mr. F. G. Cuttell, 52, New Compton Street, Soho, whose workmanship leaves nothing to be desired.

It would be wearisome to the reader were I to describe each of these slices, but I think it desirable to describe several typical specimens in some detail, and this I now proceed to do.

No. I.—A greenish-grey rock: specific gravity 2·89. It has rather a mottled appearance under the pocket lens, owing to the alteration of a portion of its mineral contents into delessite, or a mineral approximating to delessite. A portion of the rock is soluble in hydrochloric acid, and the dissolved portion contains both ferric and ferrous oxide. A few crystals of iron pyrites are to be seen.

Appearances under the microscope.—This slice may be described as a net-work of felspar and augite crystals set in viridite, which in part appears to represent the original glassy base[1].

There are numerous crystals of augite scattered through the slice. Portions of each of these crystals have been altered into brownish-green granular matter. The portions which have escaped alteration are clear and colourless in transmitted light and polarise fairly well. They are not dichroic; several of the crystals are twinned, and many of them exhibit the orthodiagonal cleavage lines very distinctly.

Most of the felspar crystals exhibit the characteristic twinning of triclinic felspar in polarised light, and their optical properties agree with those of labradorite. Alteration has been set up in the felspar, and has declared itself by the presence of granular matter in the body of the crystals.

The grouping of the felspar crystals, and the general effect of the slice when seen by transmitted light, is illustrated in fig. 1, plate I. It is very characteristic of an eruptive rock.

The viridite, in this slice, is of pale green colour. It is feebly dichroic in patches, and, for the most part, remains dark between crossed nicols. It exhibits little or no fibrous or radiating structure.

Scattered through the mass is some white mineral matter that is perfectly opaque in transmitted light, and which, from its appearance and mode of occurrence, is I think, leucoxene, a product of the alteration of ilmenite.

No. 2.—A greenish-grey rock. Specific gravity 2·90. It has a slightly mottled look under the pocket lens, but minute prisms and irregular crystals of felspar are visible in it here and there.

Microscopic aspect.—The most prominent objects in the slice are the crystals of felspar, of various sizes and shapes, starred about in the field of the microscope. The great majority are distinctly seen to be crystals of triclinic felspar, and the others appear to belong to that system also. They are in fairly fresh condition. Fig. 2, plate I, is a representation of a portion of this rock, as seen under the microscope by transmitted light.

Those who are not familiar with the subject of microscopic petrology, may be surprised to find that the prisms of felspar, represented in these illustrations, do not present more regular forms. It must be remembered, however, that the principal axis of crystals in an igneous rock usually point indifferently in all directions,

[1] This supposition is confirmed by an examination of the basalts of Bombay, to be described in my next paper. In the Bombay lavas the conversion of the *base* into viridite can be distinctly traced.

and a slice made at random cuts the crystals contained in the matrix in every conceivable direction For instance, in fig. 10, plate II, supposing a slice of the crystal therein represented were made in the direction from *a* to *b*, the outline of the section, as seen in the field of the microscope, would present a considerable modification of the true shape of the crystal.

Other causes also operate to produce irregularities of shape. Crystals forming in the proximity of other crystals appear to be sometimes stunted in their growth owing to crowding; whilst the different degrees of crystallographic energy with which the constituents of different minerals come together appear to exercise more or less influence on crystals forming in their vicinity. The want of perfect molecular freedom, when an eruptive rock is rapidly cooled at the surface of the earth's crust, must also affect the results. This freedom of molecular action becomes less and less as the cooling proceeds; hence crystallisation is often arrested before the outward form of a crystal is finished; portions of the magma are cooled before the chemical elements contained therein have had time to combine to form crystals—leaving here and there what is termed a "glassy base." The molecules of other crystals, again, coming together with energy, and being, so to speak, pressed for time, catch up portions of the glassy base and small crystals of other, previously formed, minerals, and enclose them in their own substance.

Another cause to which irregularities of outward shape are due, is the alteration which minerals undergo, after the consolidation of the rock, by the passage through it of acid and heated water. Cracks are formed both in the body of the rock, and in individual crystals, by the contraction due to cooling and to crystallisation, and along those fissures heated and acid water, or steam, penetrates; chemical action is set up, and, amongst the results, the outward form of crystals is often much altered.

The slice under consideration contains a good specimen of those radiating and cruciform groups of felspar crystals which are so characteristic of eruptive rocks. Some of the radiating prisms exhibit the twinning characteristic of triclinic felspars. The twins appear to be arranged in groups, in each prism, and the whole combined as penetration twins. A sketch of one of these groups is given at fig. 1, plate II.

No. 3.—A greenish-grey compact rock. Specific gravity 2·93.

Microscopic aspect.—This slice contains numerous felspar prisms pointing in all directions. Most of them are distinctly seen to belong to the triclinic system. Numerous instances of stellate grouping of felspar prisms occur in this slice. One of them is depicted at fig. 2, plate II. Alteration has been set up in the felspar, and shows itself by the formation of granular matter and patches of viridite in the interior of the crystals.

Fields of pale amorphous viridite are abundant in the slice, and in them are located multitudes of epidote crystals, many of them presenting good characteristic crystallographic forms. They are principally located round the margins of the viridite fields.

The remains of augite crystals are to be distinctly made out, but they have all been, more or less, converted into a greenish-brown non-dichroic substance.

Portions of the slice here and there are obscured by an alteration product, white in reflected and purplish black in transmitted light.

Nos. 4 and 5.—A dull greenish, or greenish-grey, compact rock, weathering light brown. Specific gravity 2·83. Under the pocket lens it has a somewhat mottled appearance.

Microscopic aspect.—The slice consists of crystals of felspar and augite starred about in what represents the original base or magma. This probably, as seen in many basaltic rocks—in the Bombay basalts and some Vesuvian lavas for instance—was originally full of minute grains of magnetite or ilmenite and imperfectly crystallised matter, and this has been changed into an alteration product which exhibits no crystallographic form. It is white in reflected and opaque in transmitted light.

Augite in this slice is very abundant; twinning is common in it; sometimes the orthodiagonal cleavage lines are very distinct, whilst in other crystals the characteristic intersection of the prismatic cleavage lines is well seen.

The unaltered portions of the augite are fresh and polarise well, but much of it has been transformed into a brownish-green substance.

Fig. 4, plate II, is an illustration, taken from slice No. 4, of the way in which the augite crystals have been eaten up and converted into this substance. The fragments shown in the illustration appear to represent the remains of a group of augite crystals originally in close juxta-position to each other, but which have now been split up into a little archipelago of augite fragments. The alteration which has taken place in these cases can be distinctly traced to the passage of water along cracks, and the alteration can be seen in all its stages in the slices under consideration.

Fig. 7, plate II, represents a twinned augite in slice No. 4, in which great irregularity of outward form has to some extent, at any rate, been produced by the corrosive agency of acid water, but in which internal alteration through cracks has not proceeded as far as in fig. 4. Under the microscope the dark lines which traverse the crystal are distinctly seen to be little canals filled with the products of aqueous alteration.

In many cases the alteration of the augite has resulted in the formation of mica. Fig. 5, plate II, is an illustration of a case, taken from the slices under consideration, in which part of an augite crystal (*a*), the external outline of which has been rendered irregular by its change into a greenish substance, has been converted into mica, as at *b*; whilst another portion (*c*) appears to be in process of conversion into this mineral. Another illustration is given at fig. 6, plate II, also taken from one of these slices, in which small fragments of augite are seen to be encased in mica. Doubtless the latter is an alteration product, resulting from the change of a large augite crystal, small fragments of which escaped conversion. The little canal-like cracks through which the corroding liquid originally gained access to the heart of the augite, are still visible, and an attempt to represent them has been made in the sketch.

Mica is scattered about rather plentifully in these slices, and in transmitted light, it varies in colour from red to green.

Bischof[1] alludes to the conversion of augite into a brownish, or leek green, mica. Some augites contain as much as 11·05 per cent. of alumina (J. D. Danas' "System of Mineralogy"); whilst, according to the same authority, some micas contain as little as 9·27 per cent. of that constituent. All that seems essential for the conversion of the one mineral into the other, is a removal of a large proportion of the lime from the augite and the introduction of the alkaline element—a process which one can readily understand taking place in the "wet-way."

The felspar crystals have been so kaolinised and altered that all trace of twinning has been obliterated.

I have detected one small prism of hornblende. It is probably an alteration product.

No. 6.—A compact grey rock faintly tinged with green. Specific gravity 2·92.

Microscopic aspect.—The base has been converted partly into an amorphous substance, bluish-white in reflected and olive green in transmitted light, and partly into granular viridite. In this base felspar crystals are scattered about in immense profusion, some in minute needle-shaped prisms, and others in prisms of some size. A large proportion of them exhibit the characteristic twinning of triclinic felspar. Some of the medium-sized crystals have caught up portions of the base in the act of crystallisation, and the portions so included conform to the shape of the felspar prisms.

The slice contains some good-sized crystals of epidote.

No. 7.—A grey, compact, amygdaloidal rock. Specific gravity 2·88. The centres of the amygdala consist of quartz, the inner lining being sometimes composed of epidote. Epidote is also seen to line cracks and to abound in the vicinity of the amygdala.

Microscopic aspect.—The slice consists of countless felspar prisms, starred about in a felspathic cryptocrystalline base. A large proportion of the felspar exhibits the twinning peculiar to triclinic felspar. A considerable amount of epidote is seen dotted about in small granules and in meandering lines. Here and there patches of viridite are seen throughout the base.

Amygdaloidal cavities occur here and there, filled with quartz, epidote, and delessite. The quartz is greatly crowded with a fine dust of opaque matter, which, on the application of high powers, is seen to consist of a multitude of extremely minute gas and liquid cavities.

A sketch of one of the stellate groups of felspar crystals before alluded to, contained in this slice, is given at fig. 9, plate II. The illustration shows the appearance of the group in polarised light with crossed nicols.

For the sake of comparison, I have given at fig. 8, plate II, a sketch of a triclinic felspar group taken from a slice of domite, in my possession, made from a specimen collected by me on the Puy de Dome, Auvergne. All the radiating prisms are seen in polarised light to be many times twinned, but they are arranged in groups which simulate the twinning of the Carlsbad type.

I have often observed this peculiarity in plagioclase, and it appears to be produced by one set of twins being thick at one side of the prism and thin at the other side; whilst the second set of twins are thick on the side in which the first set are thin, and thin on the side in which the first set are thick. The

[1] Chemical Geology, Vol. II, p. 326.

effect of this peculiar arrangement therefore is, that, when viewed in polarised light, one-half of the prism appears almost wholly dark, whilst the other half exhibits an almost unbroken sheet of colour; the twins which at that azimuth suffer extinction of light being very thin relatively to the twins which at that azimuth polarise in more or less brilliant colours.

This arrangement may be traced in fig. 8 sufficiently, perhaps, to make my meaning clear; but I have attempted in this sketch to reproduce the general effect, as far as that can be given in black and white, rather than these minute details of structure.

Throughout the base are scattered granules of black opaque matter that appears to be magnetite arrested in the act of crystallisation. A sketch of one of these granules, as seen with the aid of somewhat high power, is given at fig. 11, plate II. Forms of this kind appear to me to indicate that the rock cooled rapidly under conditions that interfered with the molecules of the ferriferous mineral coming together in the form of a regular crystal. As pointed out by Dr. Sorby, there is a strong tendency on the part of crystals formed in slags to assume skeleton forms, and I have noticed that salts crystallised rapidly on a glass slide very frequently assume the sort of skeleton form shown in fig. 11, instead of regular crystals; each salt, speaking broadly, having its own pattern. Skeleton crystals of magnetite, similar to those occurring in these rocks, appear to be very characteristic of volcanic rocks and furnace slags[1].

A few flakes of a reddish mica are to be seen in this slice.

No. 8.—A grey, compact, amygdaloidal rock. Specific gravity 2·84. A reddish mica is seen here and there in amygdaloidal cavities, associated with the other minerals therein.

Microscopic characters.—Prisms of felspar, much of which is distinctly seen to be triclinic, are scattered about in a felspathic base. Amongst the felspar a striking case of cruciform penetration twins is to be seen. The two arms of the cross intersect at an angle of 85°.

A considerable proportion of the base is represented by minute patches of viridite, partly fibrous and partly granular. Scattered through it, there is a considerable amount of opacite in granules, representing, I apprehend, imperfectly formed magnetite. It is similar in character and appearance to that described in slice No. 7.

The amygdaloidal spaces are plugged with quartz and viridite. In some, the viridite is seen by itself; in others an intergrowth of the two has taken place, granules of quartz being surrounded by the viridite in some cases, and in others, numerous patches of viridite of various sizes and shapes being included in the quartz.

The viridite is in some places amorphous, and in others, in radiating or sheaf-like bundles of fibres. I believe it is in part delessite and in part chlorite. Round the margins of the chloritic inclosures in the quartz it passes into the vermicular form of pro-chlorite.

The quartz, which occurs both in the amygdaloidal cavities and filling what were apparently fissures, contains many flakes of a reddish mica. The quartz is

[1] Rutley's Study of Rocks, p. 154.

remarkable for containing numerous very minute rounded liquid cavities with moveable bubbles.

From the fact that the quartz occurs in the amygdaloidal cavities and from its intimate intergrowth with the delessite, I see nothing to support the supposition that it is of fragmentary origin and has been brought up with the lava stream from below. On the other hand, though liquid cavities are very common in the quartz of granite and quartz-porphyries, I am not aware of their having been before observed in quartz plugging amygdaloidal cavities. Dr. Sorby mentions a solitary case of liquid cavities having been found in some trachyte of solid character at Ponza[1] which appears to have been formed under considerable pressure. They are, however, very common in quartz veins, and to their presence principally, Dr. Sorby attributes the usual whiteness of vein quartz. The quartz under consideration is of dull white colour and it probably owes its opacity and whiteness to the same cause. The presence of the liquid cavities in the quartz of slice No. 7, and in that under consideration, may, I think, be explained on the supposition that the lava stream after solidification was covered over for a considerable thickness by other lava streams, or by stratified deposits, and that the plugging of the cracks and the amygdaloidal cavities was accomplished with the aid of highly heated water or steam *under pressure*.

There is a great thickness of trap exposed at Darang.

Nos. 9 & 10.—A greenish-grey rock with numerous amygdaloidal cavities; Sp. G. 2·77[2].

Microscopic aspect.—The amygdaloidal cavities contain scolecite. The inner kernel of some is formed of calcite, whilst fissures in the scolecite are filled with this mineral. The study of these amygdala under the microscope affords an illustration of how one might often be misled by a chemical analysis. Viewed macroscopically the calcite would probably escape observation altogether.

The base is cryptocrystalline, and it contains multitudes of tufts of a fibrous chloritic mineral. Numerous small patches of viridite are also to be seen scattered through the mass. There are patches of a greenish mica both in the matrix and the amygdala.

Granular epidote is plentiful. A fine group of epidote crystals is imbedded in the scolecite.

The stellar arrangement of the felspar crystals may still be traced, but the felspar is a good deal altered, and no distinct indication of the twinning of the triclinic system remains.

No. 11.—A greenish-grey compact rock, Sp. G. 2·81. There are numerous round lumps of delessite plugging what were apparently amygdaloidal cavities. Other such cavities are seen to be lined with a dull reddish-brown mica. The centres of the cavities are filled with quartz.

Microscopic aspect.—The slice consists of numerous crystals of felspar of various sizes starred about in a fibrous translucent ground mass, olive green in

[1] Quart. Journ. Geol. Soc., London, Vol. XIV, p. 484.

[2] This is within the minimum for basalts, but it is probably somewhat under the mark owing to the presence of air in some of the unfilled or partially filled amygdaloidal cavities. The presence of scolecite and calcite in the latter must also affect the result.

transmitted light. More dense and opaque patches of the same material are dappled about in it in a spotty way, whilst, here and there, along what were apparently lines of infiltration connecting amygdaloidal cavities, it assumes a ropy appearance.

Most of the felspar crystals are distinctly triclinic and are in prismatic forms affording rather sharp outlines. In some instances they have caught up portions of the olive green base in the act of crystallization, the base being moulded to the form of the felspar prism.

Fig. 3, plate I, is a representation of a small portion of this slice, as seen in the field of the microscope. Annexed to a group of plagioclase felspar crystals one of the cruciform arrangements of felspar prisms, so often alluded to in the preceding pages, is seen to be attached. The arms of the cross intersect at an angle of 83½°, and they exhibit the twinning peculiar to the triclinic-system. The two long dark lines in the group above the cross are portions of the base caught up in the act of crystallization. The amount so caught up in the present instance is small, but occasionally, in some of the slices described in this paper, the amount is considerable relatively to the size of the prism.

Some of the amygdaloidal cavities are plugged with delessite in fan-shaped and radiating forms; others contain, intermingled with the delessite, a mica, red in transmitted light, and a little quartz.

Epidote is abundant, and occurs either in or connected with amygdaloidal cavities.

Mandi Traps.

The traps seen in the bed of the Suketi river at the town of Mandi occur in the line of strike of those at Darang. The outcrop is here much thinner than at the latter place.

I have examined seven sections of the Mandi trap made from chips and two from slices of the rock. There is no perceptible difference in the character of these specimens, and it will suffice to describe the two slices.

Nos. 12 and 13.—A dark-grey compact rock with a slight tinge of green in it; Sp. G. 2·88.

Augite is abundant. Some of the crystals are fairly regular in shape and twinning is common in them. A little mica is visible in these slices.

A cryptocrystalline or partially devitrified base, forming irregularly shaped spaces, is to be seen here and there. The felspar prisms do not present sharp outlines, and they are kaolinised and decomposed. No trace of triclinic twinning is to be seen in them.

The olive green ground mass has been partially converted into viridite, which is only seen, however, in minute patches disseminated through the mass.

The rock is evidently a lava that has rapidly cooled, the augite being the only mineral that has had time to crystallise regularly and perfectly.

Conclusion.

The specific gravity of basalt ranges from 2·76 to 3, its mean specific gravity being 2·90. The specific gravity of the traps described in this paper ranges from 2·77 to 2·93, their average being 2·86. The specific gravity test therefore points to these rocks being classed as basalts.

The microscopical examination of thin slices supports this view. Augite is generally abundant in them; plagioclase forms a prominent component in most of the slices; and, in those in which the twinning peculiar to triclinic felspars is not visible, its absence is satisfactorily accounted for by the kaolinisation and alteration of the felspar.

Olivine is usually one of the first minerals in a basalt to undergo decomposition, and it is often represented by a green product of alteration.[1] Olivine has not been detected. Its presence was not to be expected in a rock which has undergone considerable alteration, and, moreover, though its occurrence is very common, it is not present in all basalts. None of the Bombay basalts I have examined contain any.

Magnetite is plentifully represented in these slices by skeleton crystals arrested in the progress of crystallisation, and also by the secondary products of its decomposition.

Mica often occurs in basalts. Its presence in these slices appears to be due to the alteration of some of the original minerals.

The epidote, calcite, delessite, pro-chlorite, and scolecite, are also the secondary products of the decomposition of some of the original constituents of the rock.

Quartz only occurs in amygdaloidal cavities and cracks, and its presence in such situations is not unusual.

The mineralogical contents therefore of the thin slices examined under the microscope, agree with the specific gravity test, and show that those rocks are altered basalts.

Basalts are classed as volcanic rocks, and the fact that the traps under consideration are abundantly amygdaloidal, and that the microscope reveals the presence in them of a glassy or imperfectly crystallised base, shows that they were consolidated at the surface of the earth's crust. All the details of their structure corroborate this view, and I think they are without doubt altered basaltic lavas.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Portion of a slice of an altered basalt. Darang, in the Mandi State, North-West Himalayas.

Fig. 2. Ditto ditto.

Fig. 3. Ditto ditto.

PLATE II.

Figs. 1, 2, 3, and 9, illustrations of stellate grouping of felspar prisms, characteristic of eruptive rocks, and basalts in particular, taken from the Darang basalts.

[1] Rutley's Study of Rocks, p. 254.

Fig. 8. Another illustration of stellate grouping of triclinic felspar taken from a domite, Auvergne.

Figs. 4 and 7. Augite crystals in process of alteration into a green product by the passage of corroding liquids through the rock.

Figs. 5 and 6. Pseudomorphs of mica after augite, taken from the Darang basalts

Fig. 10. Illustration showing the modified shape of sections of minerals, as seen in thin slices under the microscope.

Fig. 11. Skeleton form of magnetite taken from one of the Darang basalts.

Further note on the connexion between the Hazára *and the* Kashmir Series—*By* A. B. WYNNE, F.G.S., *Geological Survey of India.*

The recent appearance of Mr. Lydekker's latest paper on the geology of Kashmir (Rec. Vol. XV, p. 14) throws so much more light upon the question of the relations of the rocks in two adjoining regions that I am tempted to offer a few further remarks in continuation of my last papers on Hazára.

We are now enabled to extend the comparison which I applied to the then known Kashmir section (Rec. Vol. XII, p. 128, &c.), so as to embrace the actual continuation of the Hazára rocks as they pass thence into Kashmir and Kaghán as follows, the annexed list including all the main groups of the whole region on both sides of the Kunhar[1]-Jhelum valley which appears to have been the main drainage outlet of the area from an early period :—

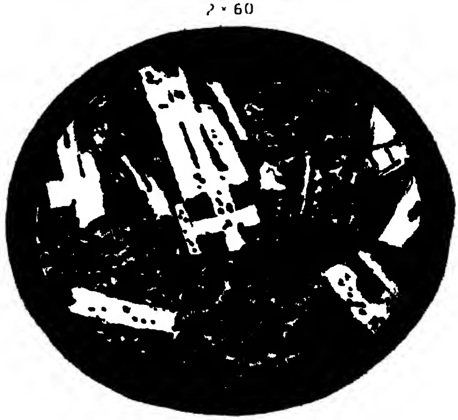
HAZARA.	KASHMIR AND KAGHAN.
7. Murree Beds (probably partly miocene).	7. Murree Beds (miocene).
6. Nummulitic.	6. Nummulitic.
PRESUMABLE OVERLAP.	OVERLAP AMOUNTING TO UNCONFORMITY.
5. Cretaceous (feebly fossiliferous).	5. Absent or unknown.
4 { Jurassic. / UNCONFORMITY, ? VERY LOCAL. / Triassic upper and lower.	UNDETECTED OR ABSENT. / 4. Trias and ? Jura.
3. Infra-Triassic and Tanól group.	3. Carboniferous.
UNCONFORMITY (STRONG).	UNOBSERVED.
2. { Attock Slate of Northern Punjab. / Trap division absent. } Silurian.	2. { Aqueous. / Traps.
1. { Schists. / Gneiss (primitive).	1. { Newer gneiss including representatives of 2 and 3. / Gneiss (primitive, Central).

This comparison will be seen to present some advance beyond that of my former paper (Rec., Vol. XII, p. 128), in which, as Mr. Lydekker observes, the schists of North Hazára are not separately included, because his Kashmir sections quoted offered nothing with which to compare them, and they could not be introduced as

[1] This Kunhar river is also called the Nainsúk, by which name I first knew it.

1 × 30

2 × 60



3 × 85

Figs. 1 to 3. [illegible] from the original drawings at the Surveyor General Office Calcutta

Fig 1

Fig 2

Fig 3

Fig 4

Fig 5

Fig 6

Fig 7

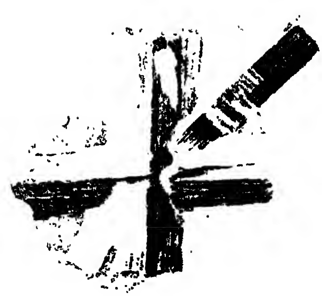


Fig 8

Fig 9

Fig 10

Fig 11

Reproduced [illegible] original drawings [illegible] General's Office, Calcutta, [illegible]

absolutely unrepresented, when they were found to pass out of the Hazára district, into then unexamined ground.

They have a position in the list nevertheless, where they are placed together with the Infra-triassic and Tanól series as he partly suggests; the Tanól portion of this set of rocks passing, as stated, into crystalline, *i.e.* metamorphosed, rocks and gneiss.

The identity of the gniess in both areas is now established and that also of the next adjoining beds.

The Attock slates are shown to be those of Kashmir, and their Amygdaloid division is approximately placed.

The carboniferous horizon is not much more clear, but the trias beds are identified, and the Murree beds are now known to be partly miocene, at all events.

The main points of difference appear to be as follows :—

HAZARA SIDE.	KASHMIR SIDE.
1. Presence of a cretaceous horizon.	Its absence.
2 Partial separability of the trias and jura, with a local discordance.	Usual blending of these without discordance.
3. Presence of an infra-triassic or lower division of the trias.	Occurrence at the horizon of a carboniferous group.
4 Presence of a thick group of Tanól beds identical or partly so with the foregoing.	Apparent absence of these beds.
5. Absence of an amygdaloid series in the silurian Attock slates.	Presence of an inferior silurian amygdaloid group.
6. Presence of a complete sub-trias discordance.	Absence of this feature or its imperceptibility.
7. Concealment or obscurity of a sub-tertiary overlap discordance.	Presence of a sub-tertiary break and overlap.

The main points of agreement are these :—

HAZARA SIDE and KASHMIR SIDE.

1.—Similarity of tertiary group in both.

2.—General similarity of the newer or perhaps upper half of the mesozoic rocks with small exceptions.

3.—Similarity of the lower palæozoic silurian-Attock-Kashmir slates.

4.—Similarity of the schists and gneiss.

5.—Universal disturbance.

It seems from the lists that the points of difference are equal in number to the main rock-groups, and those of agreement are rather more than half as many as the differences.

1. The cretaceous horizon established in the Sirban sections in Hazára and at great distances to the eastward in the Himalayas may well be present in other places though unrecognizable, as appears frequently to be possible even in Hazára.

2. The triassic rocks in this region being yet known to present in one place only (at Sirban) all the conditions as to definite zones and sufficiently fossiliferous ones, to enable detailed separations to be carried out, it seems most probable that the mixed character or the unfossiliferous condition of the Kashmir and Kaghán rocks is the general rule in both areas. The definite horizon may

of course exist everywhere, but under impenetrable obscurities, and even the appearance of discordance fairly established between these and the Spiti shale jurassic of Sirban being quite unpronounced elsewhere in Hazára, it may well be lost to sight in Kashmir.

3. The fact that Mr. Lydekker finds the carboniferous group of Kashmir vanishing into obscurity northwards, where its fossils disappear, is strongly indicative of the same unfortunate occurrence in Hazára and the consequent impossibility of defining its position closely, while it may be fairly surmised that the Hazára infra-triassic Tanól rocks or some portion of these are equivalent to the carboniferous group of Kashmir.

At the same time the idea suggests itself that the Sirban trias may really exhibit only a higher portion of the whole great group which may be elsewhere represented by more obscure older developments more widely spread, and that the carboniferous representatives may be found or supposed to exist amongst the lowest layers of these and partly amongst the likewise unfossiliferous strata of the Tanól group.

4. This Tanól group presents one of the greatest difficulties in reconciling the structure of the two regions as at present interpreted. Its thickness renders the absence of its recognition in Kashmir, &c., strange; and its place is peculiar, lying exactly between the now well-identified Attock-Ladák slates and the metamorphic schists (including rocks of different horizons), into which the same Attock-Ladák slates are supposed by Mr. Lydekker to merge by reason of increasing metamorphism.

These Tanól rocks, or their congeners, the infra-triassic, one or both, extend towards and into the lower part of the Kunhar valley, but crossing this no place is found for the group in the series of Kashmir and Kaghán, and a short line, obliquely crossing the valley from the Lachi Kun nummulitics to the Hazára older gneiss near Bálakot, marks the approximate boundary between the Attock-Kashmir slates and their supposed more highly metamorphosed continuation into the "newer gneiss" northwards. South of this boundary, however, between Bálakot and Gharri Habibula on the flanks of the Lachi Kun mountain, the Kashmir-Attock slates are not typical Attock slates at all, but more allied to the metamorphic schists. This point would so far favour the supposition that a northerly transition was taking place from less to greater metamorphism; but not far south of Gharri Habibula the slates possess their normal character, and appear projecting unconformably from beneath infra-triassic or Tanól quartzites and dolomites. The supposition that the Attock slates are the same to any extent as the schists to the north which pass into or are scarcely separable from the Tanól beds would then demand the incredible conclusion that both an unconformity and a transition between the older and newer groups should occur in the immediate neighbourhood of Gharri Habibula,—a view in which I cannot coincide.

Although the Tanól or infra-triassic beds fall readily into none of the Kashmir sub-divisions or have not been admitted into any, I certainly found them on the right bank of the Kunhar at the place last indicated, and saw at least one small tongue of them crossing the river. It seems marvellous if some representative of these dolomites, quartzites, argillaceous and other rocks does not also occur to the east, because, although in discordant relation with the silurian slates on their southern side, they have been found to mingle gradually with the schists to the northwards, which in their eastern extension become the "newer gneiss" of various ages, and also because dolomites and quartzites are mentioned among the rocks of Northern Kashmir.

If the group has an extension to the eastward, there seems, however, not much more likelihood of its being closely identified among the "newer gneiss" series than either the metamorphosed silurian or carboniferous members of that division. Connected with one or both of these groups, rocks of Tanól aspect might occur, though without sufficiently distinct grouping or identity to have urged their separation.

5. Had they possessed this distinctive character, there would only have been the absence of the apparently fugitive volcanic amygdaloids from amongst the Hazára slates to have caused any very prominent disparity between the general series in these two areas. The horizon or horizons of this amygdaloidal silurian group or groups being rather uncertain, but still placed below the slates or in their lower portion, the idea is suggested whether some of those volcanic rocks may not represent the horizon of the Tanól group, but this question I have not sufficient evidence to follow out.

From what I know or can gather of the general aspect of the geology of the whole region, I should rather expect to find the principal portion of the Tanól beds occupying a carboniferous or other intermediate horizon between the uppermost slates and the lowest fossiliferous triassic rocks.

So far the obstacles, as it were, to extending either the full Kashmir colouring of the map into Hazára, or *vice versâ*, have been noticed; the question of the arrangement of the groups is another matter.

In the parts of Kashmir and Kaghán, most adjacent to Hazára conformity real or apparent would seem to be the rule throughout the whole sequence. From an inspection of Mr. Lydekker's map and from his remarks it would appear evident that this conformity of the tertiaries north of Mozufferabad upon the palæozoic rocks assumes the nature of an overlap, amounting to the total discordance which I had already indicated from limited observations (Rec. XII. p. 127).

The unconformity at Sirban, in Hazára, where the infra-trias is not only discordant to but contains derived fragments of the Attock-Ladák slates, is established. It appeared to me to occur again without the derivative feature near the road from Abbottabad to Mánsahra and also on the right bank of the Kunhar river south of Gharri-Habibula, and yet it does not appear to have been detected in Kashmir or Kaghán, where secondary rocks occur within 12 and 32 miles of the Gharri locality, roughly speaking.

This unconformity proves so complete a break between the infra-trias and the silurian that I held myself prepared to find those of the Tanol beds most nearly identical with the infra-trias of Sirban completely discordant to the Attock slates at any place where they might occur in junction with these.

This appeared to be the relation of the groups on the lower Sirun and Dore rivers near the Indus.

The disturbance in most places greatly concealed or quite obscured any identification of this relation in connexion with the silicious and dolomitic bands of the Tanól group, while in many instances they appeared to be simply intercalated with the other Tanól beds; besides, there was always the possibility in consequence of the break at Sirban that infra-trias rocks of other places might exhibit a larger thickness of themselves or of other subjacent conformable beds. I was therefore the less surprised to find great irregularities and sudden development or reduction of the unconformable infra-trias (presumed to be in some degree equivalent of Tanól rocks) in various localities, nor did it appear improbable that the unconformity so clear at Sirban should be obscured by being removed further elsewhere from the dolomites and quartzites, or altogether lost to view in the more metamorphosed area of the schists.

Whatever portion of the Tanól beds may be identical with the infra-trias will carry with it much of the associated and stratigraphically united Tanól rocks not largely developed, if at all, at Sirban. The place of these Tanol-infra-trias beds must lie at the upper side of the discordance there, and it is impossible in so limited an area to place on the same horizon any rocks supposed to form a part of the Attock-Ladák silurians on the lower side of this discordance.

To say that the dolomites and quartzites of the Tanól area are not infra-trias but metamorphosed trias-jura, will provide no escape from the dilemma, for the trias and infra-trias have always been found as part of the same conformable sequence.

In one way it seems still possible to reconcile some of the discrepancy between the Hazára area and that to the east. I offer the suggestion with much reservation on the supposition that the rocks of both regions pass northwards into a metamorphic *terra incognita*, where important divisions become undistinguishable and the clearest indication of stratigraphic arrangement at low or high angles are untrustworthy. This being granted (if possible) it may be that the schistose series (newer gneiss of Lydekker) represents among its other constituents a lower portion of the Attock-Ladák silurian, or even the same beds as are elsewhere unmetamorphosed; that over these the schists passing upwards and uniting with the Tanól group (on an extension of Mr. Lydekker's hypothesis) represent the carboniferous and triassic horizons. Some of the dolomites, &c., of the Tanóls belonging to the former, and others with their associated slates, &c., being the unconformably enfolded representatives of the trias and infra-trias or "trias-jura" division, all in a metamorphosed or sub-metamorphosed state.

At this distance, both as regards time and place from the region and its examination, one is apt to have a less lively faith in his own deductions, and yet after reconsidering the question with the aid of Mr. Lydekker's paper, unless the perplexities of mountain structure will endorse so large a draft upon speculative hypotheses as the above suggestions demand, I am unable to see in what way the interpretations of Hazára Kashmir and Kaghán can be brought into closer concordance.

Notwithstanding that I am ready to admit any reasonable amount of possible misinterpretation not of a glaring nature amongst the obscure stratigraphical features of a metamorphosed and disturbed mountain region, the greater difficulty presents itself that it is not so much obscurity of the stratigraphic relations in Hazára as the reverse which has led to my interpretation of the district, and that no amount of the inversion, which it is now the custom to call in aid so largely, can set aside local deductions from such physical facts as the Sirban infra-trias unconformity.

Notes on the Umaria Coal Field (*South Rewah Gondwána basin*)—*By* THEODORE W. H. HUGHES, A.R.S.M., F.G.S., *Geological Survey of India.*

Owing to the great interest that has been aroused regarding the occurrence of workable coal at Umaria and in the Johilla valley in the Rewah territory, I have no doubt that a short notice relating to it, preliminary to a fuller description in our Memoirs, will be generally acceptable. Under ordinary circumstances the publication of the facts in connection with the coal would not have taken place until next year, by which time the map of the larger area to which this ground belongs would have been completed. So many enquiries, however, have been set on foot, as to the extent of the coal, its thickness, the quality of the coal and the facilities for working it, that it has become a duty to respond to them without delay.

Previous notice.

In a previous volume[1] of the Records of the Survey, I have described the geological position of the Umaria and Johilla coal. Its proper place is amongst the true or older coal-measures of India, and it is not to be confounded with the younger coal of the Mahanadi, Lameta Ghat and Jabalpur. This is a favourable point, and it implies that the coal will be moderately steady both in quality and quantity, features which are not characteristic of the newer coals.

Captain Osborne, 1860.

Many years have elapsed since the original discovery of the coal that I am writing about. The first who drew attention to it was Captain Osborne, the Political Agent of Rewah in 1860. Afterwards some Royal and Civil Engineers reported on it, but their recommendations were not strong enough to induce any active steps being taken to explore the field. Subsequently, and quite recently (1881), it was my good fortune to meet with a gentleman in charge of the Rewah administration[2] who responded cordially to my suggestions that the coal-measures should be tested near Umaria and in the Johilla valley; and within a few weeks of my broaching the plan of operations, boring tools were got ready, and Mr. Stewart, who had previously been in charge of the Narbada trial borings, was appointed, on a salary of Rs. 420 a month, to test the various sites indicated by myself. It is a great satisfaction to be able to say that the word *success* may be freely used. An abundance of coal has been proved; a large area has been determined; the con-

[1] Records G. S. I., Vol. XIV, pages 313—315.

[2] Captain Barr, Political Agent, Baghelkhand, and Superintendent, Rewah State.

ditions for working are favourable; the quality of the coal is fair in the laboratory, and the practical results are satisfactory.

The accident of position has caused much more attention to be devoted to the Umaria than to the Johilla area, the former locality being 14 or 15 miles nearer to the station of Kutni, on the East Indian Railway. The Johilla valley was merely looked at in case the Umaria borings should fail to realise the expectations formed of them. The extra distance would have been a very small drawback, if the only alternative left of procuring coal had been the opening-up of that part of the district; and it was deemed advisable, while means were at hand for under-ground exploration, to make as effective use of them as possible.

As matters have turned out, there was no necessity to have taken the precaution of examining the Johilla coal lands, but the information that has been gained respecting them is a valuable item added to our positive knowledge.

First boring at Umaria, 22nd January 1882.

The first boring at Umaria was commenced on the 22nd January 1882 on the site selected by myself. It was to the north of the outcrop of the coal seam, and was intended to prove the true thickness of the coal. According to Mr. Stewart's reading of the samples it is 7 feet. This may be accepted as the average thickness of the coal seam, the outcrop of which is seen in the Umrar river, running between the two villages of Khalesar and Umaria.

It would be needless multiplication of details to allude to each bore-hole section. The object with which the various positions were chosen was to test the extension of the coal both laterally and to the deep.

Had more time been at our disposal more ample results could have been achieved, but as the case stands even now enough data have been gathered to show that the seam exposed in the river extends over a *proved* area of 1½ square miles, and that it is fair to assume 3 square miles as probable and easily worked coal lands.

Second seam.

In boring No. 7*a*, immediately on the right bank of the Umrar, a second seam was met with, which is, I fancy, higher in the series than that proved in No. 1. It was again passed through in Nos. 8 and 9, and it was just touched in No. 11. It appears to be a permanent bed, so that we may calculate upon two seams of coal, which at a very low average may be taken as 14 feet thick.

Most of the borings were put down within the limits of the Umaria holding; but in order to learn something of the lie of the land between Khalesar and Lálpur on the other side of the river, I directed Mr. Stewart to start No. 6. A series of misfortunes rendered this hole and two subsequent ones useless as indicators, none of them having been completed. The question therefore as to what becomes of the coal in that direction is an open one, but I incline to think that the coal is there, and that had the borings been carried deeper they would have proved this to be the case. It is unfortunate that there should be uncertainty on the point, as, owing to this circumstance, I have for the sake of being within the mark omitted it from the calculable coal lands.

Available coal at 300 feet is about 28,000,000 tons.

I presume that I am expected to give a few figures showing the amount of coal that I consider to exist in the Umaria field. It is an unsatisfactory task to undertake, as those know who make calculations of this sort. With an average thickness of 14 feet, I think that within the area of 3 square miles there is an available amount of 28 millions of tons at a depth of 300 feet from the surface.

Dip slight.

The dip of the measures is slight, and the coal keeps well up for a long way to the deep, so that it presents great facilities for being readily worked.

With respect to the quality of the coal the only seam that could be tested in the laboratory and tried practically on the railway was the lower one.

About one hundred tons were excavated from the outcrop, and consignments were made to the East Indian and Great Indian Peninsula railways. From Mr. Pont, of the East Indian line, I heard that the working power of the coal was 41 lbs. the train mile.

From Mr. Brock, of the Great Indian Peninsula line, the most favourable result was 33 lbs. the train mile.

The Great Indian Peninsula trials show the coal in a very favourable light, and nearly equivalent to the best and freshest samples of the Karharbari field.

Considering that the coal on trial was merely surface stuff, the result is quite surprising. It is possible also that when the drivers and firemen are better acquainted with it they will be able to get still more work out of it.

Analyses made in the Survey laboratory by Mr. Hira Lal, who has been associated with me in the survey of the South Rewah coal areas, gave the following result:—

Analyses of different bands in the Umaria seam.

	a. %	*c.* %	*d.* %	*e.* %	*f.* %	*h1.* %	*h2.* %	*h3.* %	*h4.* %
Moisture (at 230° F.)	5·8	3·6	2·6	3·4	2·2	2·4	2·4	2·6	2·8
Volatile, exclusive of moisture	23 6	30·0	19·6	34·4	24·4	25·8	26·0	29·2	27·6
Fixed carbon	52·4	53·6	57·2	55·0	35·6	59·4	57 8	52·2	59·0
Ash	18·2	12·8	20·6	7·2	37·8	12·4	13·8	16·0	10·6
Caking	...	+	...	+	+	...	...	+	+
Not caking	+	...	+	...	...	+	+	...	...
Colour of ash	white.	pink white.	white.	grey white.	white.	white.	white.	white.	white.

N. B.—The band *f.* yielded about 15 % of oil and tarry matter.

The samples were taken by myself from the quarry at the outcrop. The index letters refer to the section which is—

Descending.	Inches.
a—Coal hard	6
b—Stony band	1
c—Coal bright	6
d— „ hard	7
e— „ bright	6
f— „ hard	4
g—Stone band	2
h—Coal hard	2 ft. 0
	4 ft. 8

The seam is not so thick at the outcrop as it is farther to the deep. The best coal is the lowest band, lettered *h*. It contains a high percentage of fixed carbon, which accounts for the excellence of the trials on the Great Indian Peninsula railway.

Of the bore-hole sections, I give Nos. 1 and 7*a* to show what rocks were passed through, and the thickness of the two seams.

No. 1.—*Commenced 22nd January 1882, ended 10th February 1882.*

	Feet.	Inches.
Black surface soil	1	6
Brown coarse sandstone	4	0
Grey soft „	1	6
Red coarse hard „	1	0
Yellow coarse hard sandstone	1	0
Grey earthy „	2	0
Yellow hard coarse „	1	0
Red coarse hard „ with clay	2	6
Grey hard coarse „ „	2	6
Mottled coarse earthy „	2	0
Grey hard fine „	2	0
Light brown fine hard „	2	0
Dark brown fine hard „	1	6
Brown hard „	7	6
Grey soft shaly „	1	0
Red coarse soft „	2	0
Brown fine soft „	1	0
Yellow fine soft „	1	0
Brown and yellow mottled clay	1	0
Brown shaly soft sandstone	1	0
Gray and brown shaly sandstone	1	0
Brown shaly soft sandstone	1	0
Grey fine soft sandstone	1	0
Brown clay, hard „	1	0
Grey and soft shaly sandstone	1	0
Carbonaceous shale „	5	0
Coal	8	0
Carbonaceous shale	1	0
Grey shaly sandstone	1	0

	Feet.	Inches.
Coal	7	0
Carbonaceous shaly sandstone	9	0
" shale	2	0
Coal	2	0
Carbonaceous shaly sandstone	3	0
White hard sandstone	16	0

No. 7*a*.—*Commenced 17th March 1882, ended 30th April 1882.*

	Feet.	Inches.
Dark brown sandy surface soil	16	0
" " clay and pebbles	5	0
Brown clay and sand	2	0
Light brown mottled shaly sandstone	1	0
" and red sandstone	1	0
Brown shaly sandstone	1	0
Red " "	1	0
Yellow " "	1	0
White " "	2	0
Brown and white shaly sandstone	1	0
White " "	1	0
Brown and white " "	2	0
Red and brown " "	1	0
White and brown " "	1	0
Yellow " "	1	0
Red and white " "	1	0
Brown and yellow " "	1	0
" " "	1	0
" and white " "	2	0
" " "	1	0
White and red " "	1	0
" and yellow " "	2	0
Brown and white " "	3	0
White " "	8	0
" sandstone	1	0
Brown "	5	0
Grey "	2	0
Brown "	6	0
Grey "	23	0
Carbonaceous shaly sandstone	5	0
Grey sandstone	1	0
Carbonaceous "	5	0
Grey "	2	0
Carbonaceous "	8	0
Grey "	20	0
Coal	18	0
Carbonaceous shale	25	0
Coal	11	0

Of the Johilla borings I have little to say; one was put down near the junction of the Marjada and Umarha streams and the other on the left bank of the Johila. The sections speak for themselves, and the coal appears to be better even than that of Umaria.

No. 2.—*Commenced 6th March 1882, ended 23rd April 1882.*

	Feet.	Inches.
Yellow clay (surface soil)	1	0
Brown shaly sandstone	10	0
Dark brown shaly sandstone	5	0
Carbonaceous clay	2	0
" shale	9	0
Grey shaly sandstone	2	0
Brown shaly sandstone	5	0
Coal	17	0
Carbonaceous shaly sandstone	1	0
Grey " "	1	0
Coal	3	0
Carbonaceous shaly sandstone	1	0
Grey " "	1	0
Carbonaceous " "	3	0
Coal	8	0
Carbonaceous shaly sandstone	4	0
Grey " "	2	0
Carbonaceous shale	2	0
Grey shaly sandstone	1	0
Carbonaceous shaly sandstone	1	0
Grey " "	4	0
Coarse sandstone	1	0
Grey "	6	0

No. 3.—*Commenced 13th March 1882, ended 23rd April 1882.*

Dark brown surface sandy soil	1	0
Dark shaly sandstone	1	0
Grey " "	1	0
Brown " "	3	0
Coal	17	0
Grey shaly sandstone	1	0
Carbonaceous shale	6	0
Grey shaly sandstone	1	0
Carbonaceous shaly sandstone	9	0
" shale	2	0
Coal	6	0
Carbonaceous shaly sandstone	6	0
Grey " "	4	0

The proving of the Umaria coal-field shows how valuable an adjunct to the labours of the Geological Survey are the facts that can only be discovered by a series of borings. A large area of coal has thus been proved, and our doubts dissipated; and we have now ample knowledge to direct us in our projects and plans for the future. The coal is good, and there is plenty of it. It is within *one hour's* railway journey of Kutni, and from its commanding geographical position, as may be seen by looking at a map, it is one of the most important areas of supply for Central and Upper India. It will be of immense utility to the Great Indian Peninsula railway, and to the feeders of that line; and I have no doubt that a large up-country consumption will be established.

What is now wanted is a line of rail to Umaria, and I trust it will be my fortune to see one started and completed within the next two years. There is a large grain traffic passing through Umaria, but I have no statistics to give. I have no hesitation, however, in saying that a railway would probably pay its way, though perhaps 2 to 3 per cent. of interest would be all that the capital would realise until the road was extended more to the east and served a larger area of country.

The Daranggiri Coal field, *Garo Hills, Assam*—*By* TOM D. LA TOUCHE, B.A., *Geological Survey of India.*

Immediately to the north of the gneissic range running westward from the Khasia plateau and forming the culminating ridge of the Garo hills, the cretaceous rocks in which the coal of this district occurs occupy a series of detached basins in the gneiss, and rest directly upon it. Of these basins the two largest,—marked as coal-fields on the Ordnance map, and known as the Rongrenggiri and Daranggiri fields respectively,—are situated in the valley of the Sumesary or Semsang river. In the Rongrenggiri field, which extends from about 2 miles to the west of the thanna at that place eastward to a short distance to the east of Shemshanggiri, there are, as far as I could discover, no coal seams of any practical value. A seam of good coal, 1 foot thick, occurs in a hill due east of Shemshanggiri, and at the west end of the field are several outcrops of a bed of carbonaceous shale, about 3 feet thick, which, I believe, represents the principal seam of the Daranggiri field described below. A fairly continuous section is exposed in the bed of the river and its tributaries between these beds and the gneiss on the one hand and the nummulitic rocks which occupy the centre of the basin on the other, and in these rocks only a few insignificant strings of coal and thin beds of carbonaceous shale occur.

The Daranggiri field, its position and area.—The Daranggiri field is situated on both sides of the Sumesary river, where it turns south in a long reach before cutting through the main range at Jankaray village. It is about 10 miles in length from west to east, extending from a little to the west of Daranggiri to Rengdim in the Khasia hill district, and about 6 miles in breadth from north to south, from a short distance above the junction of the Rongoli stream with the Sumesary to the Rongkhai stream on the south. On the south side of the latter river are a few outliers, but these are separated from the gorge of the Sumesary, through which the projected railway will probably pass, by some miles of exceedingly rugged ground so that they are not of much importance.

Within these limits the coal-measures occupy an area of about 50 square miles, but, as will be seen from the analyses given below, the seams which occur in the portion of the field lying between the Rengchi, Rongkhai and Lengta streams is almost, if not quite, worthless; besides which the small thickness of the seams in this portion of the field, not more than 2 feet 6 inches, would probably prevent their being worked with profit, even if the coal were of better quality. There remains, then, the western half of the field extending from Daranggiri to the Rengchi, an area of about 20 square miles, in which there is at least one seam of coal of good quality of a thickness sufficient to be worked profitably.

1. Daranggiri outcrops.—The outcrops of the principal seam in the neighbourhood of Daranggiri have already been described by Mr. Medlicott. (*Records*, *G. S. I., Vol. VII, pt. 2, p. 58)*. Besides this seam three are five others exposed in the cliffs about Daranggiri, but of greatly inferior thickness. The following section is exposed in a cliff on the east side of the Rongwi (Nongal) stream, a short distance below its junction with the Rongmadu, and may be taken as a type section of the coal-measures throughout the field :—

		Ft.	Ins.
1. Coarse yellow and brown sandstones	about	240	
2. White sandstones with bands of shaly clay rock	"	70	
3. *Coal*	"	1	
4. Shaly clay rock	"	8	
5. *Coal*	"	0	10
6. Shaly clay rock	"	4	
7. *Coal*	"	0	6
8. White sandstone with bands of shale	"	20	
9. *Coal*	"	7	6
10. Sandy shale with strings of coal in lower part	"	5	
11. *Coal*	"	1	
12. Carbonaceous sandy shale	"	5	
13. *Coal*	"	1	
14. Carbonaceous shale, base hidden under water	"	?	
	TOTAL	358	10

The section is given in natural order; dip about 5° to south-east.

In this section the beds immediately below the coal are not exposed, but on following down the stream the rise of the strata gradually brings them up until, at a short distance above the junction of the Rongwi with the Sumesary, they are seen resting directly upon the gneiss, and consist of about 200 feet of coarse purple and yellow grits and conglomerates. Similarly to the west of Daranggiri the seam may be traced rising steadily along the cliffs bordering the Rongmadu, the lower grits and conglomerates appearing beneath it, until it is overlapped by the higher strata which rest against the gneiss of Naramkhol and Tobeng hills. To the south of Daranggiri the principal seam disappears beneath the bed of the Rongwi, a short distance above its junction with the Rongmadu, but it appears again in the same stream, about 1½ miles further to the south, being bent up sharply against the gneiss of the main range, with a dip to north-east increasing in this section from 35° to 65° within a distance of 100 feet. On the same strike the seam appears to the west in the Nongalbicha stream and to the east in the Rongju below the village of Baduri, where it is nearly vertical.

2. Sumesary outcrops.—Descending the Sumesary from its junction with the Rongwi, the south-east dip of the strata brings the coal seams down to the river level about quarter mile above its confluence with the Garigithem stream. The same series is seen here as in the section at Daranggiri, except that the lowest one foot seam is absent. The dip of the beds is 2° to 3° to south-east, but slightly undulating, and becoming horizontal a little further down the river. The outcrop of the principal seam here, and in the Garigithem stream, about a quarter mile to the east, has been described by Mr. Medlicott (*loc. cit.*); it is about 6 feet thick. Further to the east the coal is overlapped towards the north by higher beds, which rest directly upon the gneiss, and occur in patches on the tops of the hills as far north as Sudugiri.

3. Goreng hill outcrop.—In the north-south reach of the Sumesary gneiss is exposed for a considerable distance above the junction of the Rengchi. This rock extends beneath Goreng hill to the Renchi, forming an almost horizontal but uneven floor, upon which the coal-measures rest horizontally. The lower part of these, about 200 feet, consists of coarse grits and conglomerates, which form a perpendicular cliff extending almost continuously round the south end of the hill. At the top of this precipice the coal occurs, but generally its outcrop is much obscured by talus. Large fragments of it, however, occur in all the streams which flow from the hill to the Sumesary and Rengchi. A good section is exposed in the Nengja stream, a small tributary of the Rengchi, about 1 mile from the latter, as follows:—

	Feet.	In.
1. Coarse sandstone, about	12	0
2. Coal, about	3	6
3. Clay rock with carbonaceous markings, about	4	0
4. Fine yellowish brown sandstone, about	4	0
Total	23	6

The beds are horizontal.

A short distance down the stream a band of carbonaceous shale, about 18 inches thick, is exposed, but in this part of the field I could not find any of the smaller seams which occur at Daranggiri.

Total amount of coal.—In this area of 20 square miles the average thickness of the seam is 5 feet 6 inches (7 feet 6 inches at Daranggiri and 3 feet 6 inches on the Rengchi); the total amount of coal calculated from these data is about 76,000,000 tons.

Quality of the coal.—The coal of the principal seam is bright black in colour, becoming brown when crushed; it contains numerous specks and nests of a brown resinous substance; it lights readily and burns freely. The seam is very free from shaly partings. The coal from the seams to the east of the Rengchi is brownish-black in colour, and much more shaly. Specimens taken from four localities have been assayed by Mr. Hira Lal, Sub-assistant Geological Survey, with the following results. To these I have added an assay of the coal from the outcrop at Daranggiri, taken from Mr. Medlicott's report, *loc. cit.*:—

Assays of Daranggiri coal.

	% 1	% 2	% 3	% 4	% 5
Moisture (at 230° F.)	11·5	6·2	2·6	3·0	2·8
Volatile, excluding moisture	33·1	39·4	21·6	31·2	40·2
Fixed carbon	47·7	51·8	4·0	14·0	27·4
Ash	7·7	2·6	71·8	51·8	29·6

No. 1.—Daranggiri, 7′-6″ seam (assay made in 1874).

No. 2.—Nengja stream, 3′-6″ seam: caking; ash, white.

No. 3.—Hill side above Rongtok stream: non-caking; ash, white.

No. 4.—Fragment from talus at outcrop in bank of Lengta stream: non-caking; ash, pinkish.

No. 5.—One foot seam in Rongwi stream above Daranggiri: non-caking; ash, greyish white.

Position of the principal seam as regards working.—Except in the south-west corner of the field, where the strata are bent up sharply against the gneiss of the main range, they are either horizontal or dip at very low angles, and there seems to be an absolute freedom from faults over the whole area. The greater part of the seam is above the level of the principal streams so that the coal might be economically extracted, and the mines drained by adits. Moreover, as the rock immediately above the coal is generally a fine clay rock, tolerably impervious to water, the mines would to a certain extent be kept dry by it.

That part of the seam which dips below the surface of the rivers would have to be got at by shafts, but the strata above the coal, consisting of about 300 feet of sandstone and shales would present no difficulty to the sinking of these. Finally, the line of the proposed railway, up the gorge of the Sumesary, passes through the centre of the field so that if this scheme is ever carried out there appears to be no reason why the coal of this field should not be worked with facility and profit.

Nummulitic limestone.—On the high ground to the east of Daranggiri, there are two patches of nummulitic limestone, indicated by surface fragments, but as they are entirely covered by jungle I was unable to determine their thickness and extent. However it is quite possible that quarries opened in them would supply lime sufficient for small buildings and other works in the field itself. At Siju on the Sumesary, to the south of the main range, is a large deposit of limestone of good quality.

In concluding I must express my thanks to Captain Maxwell, the Deputy Commissioner of the district, for the great interest he took in my work, and for the assistance he gave me, so that although I was totally unacquainted with the country when I arrived in it, I had no difficulty in obtaining either carriage or supplies.

On the outcrops of coal *in the* Myanoung *division of the* Henzada *district.—By R. Romanis, D. Sc., Chemical Examiner, British Burma (with a plan).*

HAVING ascertained from Major Spearman that the coal reported in the Henzada district was found at Mokhoung, near Hleemouk, on the Nangathoo river, I proceeded thither, leaving Henzada on the morning of April 27th and arriving at Hleemouk on the following morning. The way lies along the Henzada embankment for 25 miles as far as Kyoukywa, where the Bassein river is crossed; thence by cart-roads through rice-fields to Kwingouk, where the Nangathoo river is passed. From this place to Hleemouk is about 8 or 9 miles. The road several times enters the bed of the Nangathoo stream. The last 2 or 3 miles of the road pass through forest, but it is almost level the whole 15 miles from Kyoukywa.

I found the outcrop at Mokhoung, the site of a deserted village about 4 miles from Hleemouk. It is at the foot of a steep bank composed of clay and loose stones lying upon shales which dip to the north at an angle of 45°. The river flows along the foot of the slope, crossing the strata at right angles to the strike. At a point where there is a fold or bend in the strata, and the dip changes to the south, the coal appears as a bed 22 inches thick below 24 inches of carbon-

aceous shales. I was not able to follow the strike of the beds across the river, as there is a wide alluvial tract on the other side beneath which it is concealed, if it exists at all, nor could it be found to the south of the fault, where the beds dip to the south. As it appears at a fault, the coal is much broken by the bending of the rocks, and patches of shale occur throughout the bed, which induced me to think it a mere pocket in the shale. A watercourse, which seems to mark the line of dislocation, enters the stream at the place where the coal appears. About 100 yards further up the stream some coal was found amongst the debris at the foot of the bank; and in a watercourse which enters the stream to the north is a thin bed of carbonaceous shale under a bed of quartz.

While at Hleemouk a piece of coal was brought in, said to be from Kywaising in the Okepo district. On examining it I found that it melted and formed a coke, which the Mokhoung coal does not do. I at once proceeded to the place, which is about 12 or 14 miles from Hleemouk, near the junction of the stream, called in Fitzroy's map the Shwayneing with the Okepo river. It is not marked in that map, which appears to be incorrect in the representation it gives of this district.

On arriving at Kywaising we were conducted to the coal. It is found at a place about 1½ hour's walk from Kywaising over low hills covered with bamboo forest.

The coal appears at a sharp bend of a watercourse which flows from north to south into the Shwayneing river. At the point where the coal is exposed the stream makes a sharp turn and flows from west to east for about 120 yards. The south bank is about 50 feet high and steep. The coal is exposed along the whole of the bank in a bed about 12 feet thick. A cutting was made into the coal when the following section was found:—

	Feet.	Inches.
Soil and decomposed yellow shale	5 or 6	0
Carbonaceous shale	0	4
Coal	1	6
Carbonaceous shale	0	2
Coal	1	6
Carbonaceous shale	0	4
Coal	1	6
Carbonaceous shale	0	2
Coal	1	6
Carbonaceous shale	1	6
Coal, good quality	2	0
Coal, inferior	2	0
Total	11	6

The lower portion was concealed by debris, and the exact thickness could not be estimated. Since my return I have been informed by Mr. Lewis, who continued the work after I left, that the layers of shale become mere partings in the coal, and that there are 6 feet of coal, then 2 feet of shale, and then 4 feet of coal, the upper 2 feet of good quality.

The dip of the bed of coal is 30°, to E.

I examined the rocks in the neighbourhood and found that they dipped like the coal at 30°, to E. The strike is north and south. I observed layers of carbonaceous shale at three places in the watercourse, and found that they crossed it and passed under the opposite bank, showing that there is no fault but the strata dip under the hill to the east. Over one of these beds there lies a thick bed of quartz-breccia. From the dip of the strata and the position of the quartz-breccia and shale I conclude that they lie under the coal.

Having finished my observations at this place I visited the outcrop at Poosoogyee, in the Myanoung district. On my way through Hleemouk I revisited the outcrop there. It was too dark to see what had been done, but I was told that the coal had come to an end after four bags had been got out, and that the rest was all shale. Mr. Lewis, who saw the place by daylight, says this is not the case; there is a layer of coal 18 inches thick.

Poosoogyee is about 30 miles from Myanoung, on the Padaw river. On my way I halted at a Chin village, Yaynantoung, so named from a petroleum spring about 4 miles away in the hills. I did not visit it as the quantity of petroleum is very small, but it is evidence of the presence of bituminous strata. The spring is marked on the map as east of the village.

The outcrop of coal is about 4 miles from Poosoogyee on the left bank of the Padaw stream. It is a band varying from 18 to 6 inches in a bed of carbonaceous shale dipping 60°, to E. It is very friable, crumbling into powder between the fingers. The stratum in which it occurs is much contorted, and in one or two places the coal thins out altogether. On examining the neighbourhood I found a bed of quartz conglomerate overlying a bed of bituminous shale in two places, one further up the stream than the coal, the other lower down, dip 60° to N.E. at the latter, 60° to E. at the former, evidently passing below the coal, and thus bearing the same relation to the coal that similar beds do at Kywaising and Mokhoung, from which I infer that the same strata of coal, shale and conglomerate appear at each place. The coal is at its maximum thickness at Kywaising and thins out to 22 inches at Mokhoung, 12 miles south, and to less than 12 inches at Poosoogyee, 18 miles north. The following diagram shows the order of the strata, as it appears to me :—

Yellow shales and sandstone several hundred feet.
Coal 10 feet.
Carbonaceous shale (?)
Yellow shale and sandstone, 300 feet.
Quartz breccia, 5 feet.
Carbonaceous shale, 2 feet. (?)

I do not think that it is worth while at present to bore at either Poosoogyee or Mokhoung. At Poosoogyee the rocks are much contorted; they have been indurated by infiltration of silica; the dip is great and the seam irregular. It is possible that the irregularity is due to the twisting of the strata at the point where they crop out, and that a boring put down to the eastward may find the coal more regular and less friable, but it seems to me that the Kywaising outcrop is the one most likely to repay exploration.

I should recommend that two borings be made, one to trace the coal under the opposite bank of the stream, that is, to the eastward, the other to the southward to follow the coal towards the river. The shale and soil covering the coal on the west side of the watercourse cannot be many feet thick, and several borings may be made without trouble.

As to the question of transport, the Okepo river is navigable during the rains for boats of 10 tons as far as Kywaising. The coal is about 5 or 6 miles distant from the village. Four miles of the road are level, but the bed of the Shwayneing river is crossed several times. For the last 2 miles the road is the bed of a watercourse covered with loose stones, but if the coal is in quantity there will be no difficulty in making a path by clearing the bamboo forest and cutting a road in the hillside. Good timber may be obtained from the pyinkado trees *(Xylia dolabriformis)*, which grow plentifully on the spot. In the dry weather there is only enough water in the Okepo to float bamboo rafts, but it is only 16 miles by cart-roads to the Bassein river, and I suppose a light tramway might be laid down at small cost, if the coal is in sufficient quantity.

Analyses of coal:	*Kywaising.*	*Poosoogyee.*
Moisture	1·48	6·36
Volatile matter	26·58	18·21
Fixed carbon	65·12	69·65
Ash	6·82	5·78
	100·00	100·00

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RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1882. [November.

Notes on a traverse across some gold-field *of* Mysore, *by* R. BRUCE FOOTE, F. G. S., *Deputy Superintendent, Geological Survey of India.* (*With a map.*)

In August 1881, I made a rapid traverse north-westward from Bangalore to the neighbourhood of Honali (Honhully) on the Tungabhadra and very nearly up to the southern boundary of Dharwar District. As my route lay in most parts across a very bare and open country and I travelled by day only, map in hand, I was able to form a very fair general idea of the leading features of the country, which proved to be of much interest for comparison with the results of various traverses I had made in the South Mahratta Country, the southern part of which is formed of the northerly continuation of the great gneissic series which forms the Mysore plateau. Later in the year I connected the Bangalore end of the traverse with older work in Salem District by another traverse along the Madras railway down to Jalarpett Junction. The results of the combined traverses show that the Mysore table-land is traversed by great bands of granitoid and schistose gneiss, the southerly extensions of some of the great bands recognized in the South Mahratta Country. When the whole of this region shall have been geologically examined it is more than probable that all the bands known to the north of the Tungabhadra (see map) will be traced far to the south. The traverse now to be described shows that three great bands of schistose rock occur on the Mysore plateau, and that two of these are actual continuations of two of the great schistose bands in Dharwar districts which, in my Memoir of the Geology of the South Mahratta Country (Memoirs, Geological Survey of India, Vol. XII, p 43) I described as the Nargund and Bail Hongal (Dharwar) bands. For convenience of description these bands will in the sequel be referred to as the "Dharwar—Shimoga" and "Dambal—Chiknayakanhalli" bands. Both these bands have been traced across the Tungabhadra, the latter in a chain of hills running down southward to Chitteldrug and Chiknayakanhalli, while the former forms another chain of hills passing Harihar (Hurryur) and Shimoga and stretching further south towards Hassan. These bands are of considerable width, the Dambal—Chiknayakanhalli band, which is considerably the narrower of the two, measuring 18 miles across where crossed by the line of section. In addition to their geological interest, these two bands are of importance, as within their limits occur several of the auriferous tracts which have of late attracted so much attention. The Dharwar—Shimoga band is slightly auriferous at its northern extremity, and streams rising on it near Bail Hongal and Belowaddi in the Sampgaon Taluq of Belgaum district used formerly to be washed for gold. The auriferous tract of Honali lies within the same schistose band a little to the north of Shimoga. The Dambal—Chiknayakanhalli band contains the auriferous tract of the Kapputgode hills, near Dambal to the north of the Tungabhadra; while south of that river on the Mysore plateau, near the town of Chiknayakanhalli, are quartz reefs reported to be auriferous, and which have attracted the notice of several speculators, who have taken up land for mining purposes.

This schistose band is seen to stretch away far to the south-south-east in a line of low hills, and is said to extend to Seringapatam, passing that place and the town of Mysore to the eastward, and then trending round to the south-west and continuing into south-eastern Wynáad, where it forms the gold-field around Devala. This tallies with Mr King's observations in the Wynáad,[1] a strong band of schistose gneiss having been shown by him to occur at and around Devala, in which chloritic schists occupy an important position. My informant as to this extension of the Dambal—Chiknayakanhalli band was Mr. Lavelle, the pioneer gold prospector of the present time, who has traced the band from the Wynáad north to beyond Chitteldrug. I have no doubt but that Mr. Lavelle's observations will be fully confirmed when the whole of Mysore shall have been surveyed geologically. If the parallelism of strike continues between the southward extension of the Dharwar—Shimoga band and that of the Dambal—Chiknayakanhalli band, it is highly probable that the former will be found to constitute the auriferous tract said to exist in the North Wynáad. The stratigraphical relations of the several great bands, both granitoid and schistose, have yet to be worked out, for in the northern part of the great gneissic area they were found too obscure to be satisfactorily explained, and it remains to be seen whether they represent two or more great systems. Their position and relation are shown in the accompanying map and section.

Rocks seen along the line of section.

Eastern granite-gneiss band.

If the line of section be followed from S.-E. to N.-W. it will be seen to traverse a region of very typical granite gneiss, extending from Jallarpett Junction (Madras Railway, South-West Line and Bangalore Branch) for a distance of some 30 miles. This granite-gneiss tract forms the eastern edge of the great Mysore plateau which is here a wild, rugged, picturesque jungle region.

Kolar gold-field schistose band.

To the west the section crosses at its narrowest part the band of schistose rocks in which lies a little to the north of the railway the now well-known Kolar gold-field, at present a scene of energetic mining work on the lands taken up by a number of large mining companies. This schistose band, which will be most

[1] See Preliminary note on the gold-fields of South-east Wynáad, &c., by William King, B.A., Deputy Superintendent, Geological Survey of India. Records, Geol. Surv. of India, Vol. VII, p. 26.

appropriately called the Kolar schistose band, forms an important synclinal trough resting on the adjacent granite-gneiss rocks. It is the only one of the great schistose bands whose relations to the associated bands of granitoid rocks have (as yet) been distinctly traced. A fuller account of this band with especial reference to its auriferous character will be given further on.

Bangalore granite-gneiss band.

On crossing this Kolar gold-field band, the section trends northerly as far as the Kolar road railway station when it bends sharp round to the west and continues in that direction as far as Bangalore. The very broad band of granitoid gneiss, which extends between the Kolar gold-field schistose band to the second great schistose band (the Dambal—Chiknayakanhalli band), forms in its eastern part an open undulating plain from which rise a few important rocky hills, as the Tyakal (Tiacull of sheet 78), Balery and Vakelair hills north of the railway. A number of small low table-topped hills are also to be seen at small distances from the railway, as the Bettarayan Betta (Baterine hill of sheet 78), 3½ miles north-east of Kolar Road railway station, the Patendur hill, 2 miles south-west-by-south of the Kargudi (Curgoory) railway station, and the low hillock crowned by a mantapam about a mile north of the Maharajah's new palace at Bangalore. These three hillocks are capped with beds of true sedimentary laterite underlaid by lithomargic clays. Of precisely the same aspect, both in form and colour, are the Shiva Samudra, Jinnagra and Chicka Tagaly hills which lie a few miles north of the railway near the Kargudi and Mallur stations. Identical in form and appearance also is a much more extensive development of table-topped plateaus which are well seen from Bettarayan hill lying several miles to the north and covering a considerable area. The laterite at the north-eastern end of the Patendur hill is distinctly conglomeratic and contains a tolerable number of well-rolled quartz pebbles. The red colour of the sides of these hills and plateaus added to their sharp cut tabular shape, makes them conspicuous from considerable distances. No organic remains were found in connection with these lateritic beds, and the number of sections examined was not sufficient to enable me to form any positive opinion as to their origin, and still less so as to their geological age,—but there can be no doubt that they are the scattered outlying remains of a formerly far more extensive formation.

To the north-west of Bangalore the undulation of the country increases considerably and the streams run in much deeper channels affording more numerous sections both of the surface soil and sub-rock. The surface of the country is generally covered with a thick layer of red soil which often contains a large percentage of pisolitic iron (hæmatite) in segregational form.

Thirty-two miles north-west of Bangalore the section cuts across the line of hills running north and south from the Cauvery river, a little east of the great falls, up to Nidugal on the frontier of the Bellary district. This line of hills culminates close to the section in the fine peak of Sivaganga which attains the

[1] The expression line of hills is used in preference to the term chain as there is little continuity of high ground, the hills being mostly quite detached and separated in some parts by considerable spaces.

height of 4,559 feet above sea-level. Like many other groups of granitoid gneiss hills in the south, these hills are very rocky and bare and look as if they had never been covered with a real forest growth.

Dambal—Chiknayakanhalli schistose band.

The section maintains its north-westerly course up to Tumkur, beyond which town it turns suddenly westward and, after a course of 16 miles in which remarkably few outcrops of rock are seen, meets the second great band of schistose rocks in the line of hills rising between Hagalvadi and Chiknayakanhalli. This second great band of schists is, as will be seen by a glance at the accompanying map, the southerly continuation of the Dambal—Chiknayakanhalli schist band as defined above (page 191). The width of this extremely well marked schistose band which the section crosses at right angles is 18 miles. The character of the scenery is markedly different; smooth grass grown hills, generally well rounded, with very few conspicuous exposures of rock, take the place of the bold rocky bare hill masses seen east of Tumkur. The rocks consist of hornblendic, chloritic and hæmatitic schists cropping out at very high angles or in vertical beds. Several large quartz reefs occur traversing these schists, and one large one crosses the road some distance west of Dodygan halli. Time did not allow of my doing any prospecting here, but several prospectors have stated that their researches were rewarded by the discovery of gold in appreciable quantity both in the quartz and by washing the local soils. The extension southward of this schist band may be traced by the eye for many miles owing to the very characteristic features of the low line of heights which extends south in the direction of Seringapatam. That they extend still further south and then trend south-westward into the south-eastern part of the Wynáad may be assumed as a fact on the strength of the information kindly furnished by Mr. Lavelle, the pioneer gold prospector—(See *ante*, page 192). The contact of the schists and granitoid gneiss is unfortunately concealed by superficial deposits at the places where the section cuts across their respective boundaries, but the impression left in my mind by the general appearance of the localities was that the schists were overlying the granitoid beds, and the same relation appeared to me to exist in the Dambal gold-field, as far as its western boundary is concerned. The eastern boundary of the schist band was not traced near Dambal and Gadag (Gudduck), but further north it is completely hidden by the tremendous spread of cotton soil there prevailing. Passing on a little to the south of west from the schistose band the section runs across a granitoid gneiss region, and after passing Tripatur crosses the watershed between the Cauvery and Krishna hydrological basins, the section trending more and more north-westerly along a rapid descent. It leaves the high, picturesque, granitoid hill masses of Hirekal Gudda and Gardangiri to the right and beyond Banavar skirts the eastern boundary of the third or Dharwar—Shimoga schist band for several miles, but does not actually leave the granitoid rocks till it has passed Kadur by some six miles. The rocks of this granitoid band, which may for convenience be called the Mulgund-Kadur band, offer no speciality calling for remark. Like the hilly region running east of Tumkur, the hills may preferably be described as forming a line rather than a chain for they occur in numerous detached masses.

Dharwar—Shimoga schist band.

As just mentioned, the section gets on to the third schistose band six miles to the north-west of Kadur, and here the schists are mostly chloritic, of pale colour with intercalated more highly siliceous bands, ranging from chloritic gneiss to quartzite. To the south of the road the quartzites increase much in development and rise into a high ridge with a great cliffy scarp on the eastern face of Coancancul peak. Further west, to the south of the high road, rises a considerable hill of very rugged nature, which, when seen from a distance, presents great resemblance to a typical granitoid gneiss hill. On closer approach the rock is seen to have a very coarsely mottled structure which turns out to be due to the presence of enormous numbers of well-rounded pebbles of a granite or compact granite gneiss. The size of the included stones ranges in the part I examined from small pebbles to small boulders, all enclosed in a greenish-grey foliated chloritic matrix. The thickness of the conglomerate here exposed must be very great, as proved by the size of the hill which goes by the name of the Kal Drug (Cull Droog). To the north, the beds are soon lost sight of under the local alluvium of the Kushi (Cooshy) river and they are not seen to re-appear conspicuously in the hilly country on the north side of the valley. To the west of the great conglomerate beds follow more schistose beds, and, as seen on the hill slopes south of the road, a great series of quartzites. Near Tairakerra, and to the north-west of it, very few exposures of rock are met with as far as Bankipoor, but the few that do show through the thick woods which here cover everything, prove the country to be formed of schistose members of the Gneissic Series. About four miles north-west of Tairakerra the road crosses a very small outcrop of typical hæmatite schist, striking in a northerly direction. A good deal of rock shows in the bed of the Bhadra river at and above Bankipoor, but the forms seen are not very characteristic, and at the time of my passing everything was obscured by a thick layer of slimy mud left by a high fresh in the river. This part of the section would be very unsatisfactory were it not that the schistose character of the beds forming the line of hills extending northward parallel with the valley of the Bhadra shows quite clearly the extension of the rocks seen south-east and east of Tairakerra. Between Bankipoor and Shimoga very little rock of any sort is seen, but about half way across the Doab, between the Tunga and Bhadra rivers, a band of fine-grained grey granite gneiss is crossed, while to the east and south of Shimoga town are several conspicuous large masses of a chloritic variety of granite gneiss. The exact relation of these granitoid outcrops to the great schist series further east I had not the opportunity of determining, and am not quite certain whether they represent the eastern border of another great granitoid band, or whether they are part only of an unimportant local band of granitoid rock. I am inclined to think the latter will be found the real condition of things when the country comes to be fully surveyed. The short space of time at my command prevented my making a detour to settle this point. Here, too, the extent and thickness of the jungle growth greatly hide the general surface of the country along the road, while the rainy or misty character of the weather tended much to obscure the appearance of hills at but

Great conglomerates of Kal Drug.

very moderate distances. Though the exigencies of dâk travelling compelled me to make the detour to Shimoga instead of following the line of schistose beds northward from Bankipoor, I am perfectly satisfied as to the fact of these schists continuing northward, and joining those which cross the united rivers forming the Tungabhadra, a few miles below the junction of the Tunga and Bhadra. The country here is much freer from jungle, and many ridges of rock, consisting of quartzites and chlorite schists with rocks of intermediate character, can be traced for miles. This part of the section extends from the bank of the river for rather more than 20 miles,—from the travellers' bungalow at Hollalur north-westward to the Toancull-betta Trigonometrical station, six miles east by south of Shikarpur. Along the twelve miles of road between Shimoga and Hollalur but little is seen of the older rocks, the road lying close to the left bank of the Tunga and Tungabhadra, and passing almost entirely over the river alluvium which at and to the north-east of the Hollalur bungalow forms a coarse bed of rounded shingles, rising a considerable height above the present high flood level of the united rivers.

The most striking features both orographically and geologically of this part of the Mysore country are the quartzite outcrops, which are numerous, but of which only the principal ones require notice. Of these the best marked, longest and highest culminates in the Kalva Ranganbetta, a fine hill rising some 1,200′ above the plain, and 3,388′ above sea-level 16 miles to the north of Shimoga. The outcrop of the great quartzite beds forming this ridge has a distinct dip of some 60°-65° (on the average) to the north-east. The quartzites are underlaid by a schistose (chloritic) series, the south-westward extension of which was not ascertained. Overlying the quartzites which are generally flaggy in character (but which here and there become so highly charged with scales of pale green chlorite as almost to lose their quartzitic character, and pass into chloritic gneiss) are local beds of true conglomerate,—the first I have met with or heard of in the gneissic rock of the Peninsula. The conglomerate has evidently undergone considerable metamorphosis, but its real character and truly clastic origin cannot be doubted when carefully examined. Many of the included pebbles appear to have been fractured by the great pressure undergone, but their truly rounded character is quite distinct and unmistakable. The beds seen by me and traced for several hundred yards, are exposed a little way up the slope of Kalva Ranganbetta peak, and a little to the north-west of a small, but rather conspicuous, pagoda, which stands in a little recess. The included pebbles in the conglomerate consist chiefly of quartz, a few of gneiss, and some of what appeared an older quartzite. A second intended visit and closer examination of this very interesting bed was prevented much to my sorrow by bad weather. The second in importance of the quartzite ridges has its eastern extremity in the bed and left bank of the first west to east reach of the Tungabhadra below the Kudali (Coodly of sheet 42) Sangam, or junction. West of the new high road from Shimoga to Honnali (Honhully) the quartzite beds rise into the Phillur Gudda (hill), and beyond that rise again into a considerable hill some 400′ to 500′ high and may be followed easily for several miles to the north-west. The quartz-

Great conglomerates of Kalva Ranganbetta.

Conglomerates of Phillur Gudda ridge.

itic character is then in great measure or entirely lost by the rock becoming highly chloritic and the beds can no longer be safely distinguished from the surrounding mass of chloritic schist. In the north-westerly part of this Phillur Gudda ridge several pebbly beds were observed intercalated between the more or less chloritic quartzite. They differed from the Kalva Ranganbetta beds in being less coarse and having a more chloritic matrix, but had undergone about an equal amount of metamorphosis. A considerable number of quartzite ridges are intercalated between Phillur Gudda ridge, and the southern end of the Kalva Ranganbetta ridge, which terminates in the Nelli Gudda Trigonometrical station hill, 7 miles west-north-west of the Kudali Sangam. To these ridges may be ascribed the existence of the group of hills they occur in, as but for their greater durability and resisting power to weather action, they would certainly have been worn down to the low level of the purely chloritic part of the schistose band, both to the north-west and south-east. Unless there has been an inversion of the strata on a rather large scale, or faults exist which were not obvious during the rapid survey, the Kalva Ranganbetta quartzites underlie all the beds to the northward of it. Another series of overlying quartzites is shown to the north-north-west of Kalva Ranganbetta; but the relation between it and the upper beds just described could not be determined without a much more close examination of the district, more especially as the space between the two sets of outcrops is very largely and closely covered by spreads of regur. The chloritic schists offer no specially interesting features, and they are not, as a rule, well seen, except on the slopes of the hills, the general face of the country being much obscured by red or black soil, which both of them occur in great thickness.

The Honnali gold-field.

One remaining point of great interest is the large number of important quartz veins, or reefs, which traverse the belt of chloritic rocks overlying the Kalva Ranganbetta quartzites. They are the source of the gold occurring in the thick red soil which covers the whole face of the low-lying country, and which has been washed for gold, certainly for several generations past, by several families of "Jalgars" residing at Palavanhalli. The gold is so generally distributed through the red soil that it is clear that many of the reefs must be auriferous, and the quantity found is sufficient to justify strong hopes that a profitable mining industry may be developed by working the richer reefs. Several of the series of reefs close to Devi Kop, a little village 3½ miles east-south-east of the Kalva Ranganbetta, had been carefully and deeply prospected at the time of my visit by Mr. Henry Prideaux, M. E., and in one case certainly with very marked success. The quartz in this case was found very rich in gold, which was visible in grains and scales scattered pretty freely through the mass. The quartz in many parts had a quasi-brecciated structure with films and plates of blue-green chlorite occurring along cracks in the mass. Near the surface the chlorite, with which were associated small inclusions of pyrites, had often weathered into a rusty brown mass. The reef which at the time of my visit was regarded as the most promising, and to which the name of "Turnbull's reef" had been given, is one of a series of three that can be traced with some breaks for a distance of six miles nearly parallel with the great quartzite ridge of the Kalva Ranganbetta, the true strike of the reef being from N. 40° W. to S. 40° E. Another important set of three reefs having the same strike occurs about half a mile north of the first series, but they are not visible for such a long distance, their north-western course being covered by the thick spread of cotton soil. To the south-east they, or at least one of them, can be traced across the Nyamti nullah, which divides the gold-field in two. Out-crops of vein-quartz in a line with a south-easterly extension of this set of reefs are to be seen north and east of Palavanhalli (Pulluan hully of sheet 42). Numerous other quartz reefs having the same strike occur in the south-eastern half of the gold-field, *e.g.*, a set of four, rather more than a mile north-east of Palavanhalli, and several others to the north of Dasarhalli and south of Kunthua. A few reefs were also noticed whose strike was different from those above referred to. They represent two other systems of fissures, the one running N. 5° E. to S. 5° W.; the other, W. 5° N. to E. 5° S. Several of both these series are of very promising appearance, the "back of the lode" bearing considerable resemblance to that of "Turnbull's reef." The greater number of the reefs in the Honnali gold-field are well-marked examples of these fissure veins. The richness of the "Turnbull" and other adjacent reefs will ere long be fairly proved, as Messrs. Wilson & Co., of Madras, have, in company with other capitalists in England, formed an association to open up mines on the lands they have taken up from the Mysore Government. Their prospects of success are certainly greater than those of sundry other companies whose shares are or were till lately favourably quoted.

The Honnali gold-field appears to have been known a long time to the natives, but only came under European notice through Colonel R. Cole, late of the Mysore Commission, who not very long since received several small nuggets from a native local official, with the assurance that they came from that part of the country. The occurrence of gold both in the soil and reef has since been amply established by the researches of Messrs. Bill and Turnbull, of Wilson & Co., and of Mr. Mervyn Smith, but specially by the thorough-going system of deep prospecting followed by Mr. Henry Prideaux, the Mining Engineer employed by Messrs. Wilson & Co. Mr. Prideaux's large experience in Californian and Nevada mines had fully convinced him of the absolute necessity of deep prospecting, in other words, of preliminary mining, to get below the weathered backs of the lodes, before attempting to pronounce an opinion as to the real value of prospects. I am indebted to him for much courtesy during my stay at the Honnali gold-field and for much valuable practical information, most willingly and pleasantly imparted.

During my stay at Devi Kop, I watched the results of many washings both of crushed quartz and of the red soil taken from many localities and various levels. The great majority were highly satisfactory. The Jalgars, or local gold-washers, seem to be a fairly prosperous set of men, so their earnings must be fairly remunerative. They confine their attention, as far as I could ascertain, pretty generally to the high lying red soil banks, between Devi Kop and the Nyamti nullah. The head Jalgar, a very intelligent old man and dexterous gold-washer, informed me that the best day's work he had ever done was the finding of a small pocket in the gneiss which contained about Rs. 80 of gold in small grains and scales. I gathered from him that he had not found anything beyond the size of a "pepite." The position of these auriferous banks near Devi Kop would admit of hydraulic mining over a considerable area by a system of dams and channels to bring water from the Nyamti (Namtee of sheet 42) nullah, but the question of the profitableness of such an undertaking could only be decided by an expert after careful examination and more numerous trials by washing.

Notes on the Kolar gold-field.

The schistose band, which bears within its limits the "Kolar gold-field," forms an elongated synclinal fold which in parts rises somewhat over the general level of the surrounding granitoid country. The dip of the rocks forming the basement of the schistose band, and therefore the boundaries of the synclinal fold, is easily traced on both sides; not so, however, is the dip of the uppermost members of the group, for all the beds exposed in the centre of the band have been much altered by great pressure which has superinduced an irregular slaty cleavage to a great extent. This, combined with extensive minute jointing, has so greatly altered the original texture of the rocks that they have assumed to a very great extent a highly trappoid appearance. The lines of bedding are completely obliterated, and it was impossible to decide from the sections I saw whether the central axis of the synclinal represents one great acute fold, or a series of minor ones in small vandykes. The great petrological similarity of the strata forming the upper (central) part of the synclinal makes the decipherment of this difficulty all the greater. The sections I saw in the several shafts being sunk at the time of my visit threw no light on the subject; it is possible, however, that a closer study of these sections would go far to enable this point to be decided.

The succession of formations seen from west to east, after leaving General Beresford's bungalow at Ajipálli on the road from Kolar Road railway station to the gold-field, is micaceous gneiss (resting on the granitoid gneiss), chloritic gneiss, micaceous schist, hæmatitic quartzite, and chloritic schist, on which rests a great thickness of hornblendic schists, which, as just mentioned, are highly altered, and have their planes of bedding almost entirely effaced by the pressure and crumpling they have undergone. The eastern side of the fold shows near the village of Urigam (Woorigum, sheet 78) well bedded schists—dipping west from 50° to 60° and resting finally on the granitoid rocks. The western side of the gold-field is very clearly demarcated by a well marked ridge of hæmatitic quartzite which culminates in the Walagamada Trigonometrical Station hill, from the top of which the majority of the mines can be seen. The bedding is often vertical and highly contorted in places. The texture varies from highly jaspideous quartzite to a schisty sandstone. The hard jaspideous variety generally shows distinct laminæ of brown hæmatite, alternating with purely siliceous laminæ generally of white or whitish drab colour. It is only here and there, and over very trifling areas, that the ferruginous element ever assumes the character of red hæmatite. The beauty of the "vandykes" and complicated crumpling and brecciations of this rock in the Walagamada Konda is very remarkable. The thickness of the hæmatitic band is very considerable and it forms the most striking feature of the western side of the gold-field. On the eastern side of the gold-field the hæmatite quartzite is much less well developed and exposed, excepting in the south-eastern part of the gold-field where it occurs in thick beds forming the main mass of the Yerra Konda Trig. Station Hill. Here the dip is about 60° westerly, and affords one of the clearest proofs of the synclinal character of the schist band. To the southward the hæmatitic beds appear to coalesce the synclinal being pinched together, but I had no opportunity of following up the eastern boundary of the schistose band. The western boundary is a very conspicuous feature, a bold rocky ridge running up into the lofty Malapan Betta peak, the highest summit in this part of the country. South of Malapan Betta the hæmatitic beds appear to lose their importance and no longer form the most striking feature of the schistose band, and micaceous and chloritic beds abound. Owing to the great extent of jungle and the rugged character of the country their general relations were not to be made out completely in the short time at my disposal. The beds run south into the Salem district, and probably occupy the valley lying east and north-east of Kistnagiri and, not improbably, extend on towards and past Darampuri. A subsidiary ridge of lower elevation, which branches off from the western side of Malapan Betta westward and then trends south-west and finally south-south-west, also consists of schistose beds of similar character, amongst which a hæmatitic quartzite is the most conspicuous. The relation of these latter beds to the Kolar gold-field synclinal fold is quite problematical, but it is very probable that several important faults have caused great dislocation of the strata first along the boundaries of the main synclinal fold. The stratigraphy of the several spurs radiating from Malapan Konda is very complicated and interesting and well worthy of careful examination.

The auriferous quartz reefs which have attracted so much attention lie in the broader part of the synclinal fold north of the railway. None of any importance were seen by me in the tract south of Malapan Betta. The intermediate tract I had no opportunity of examining closely, but I did not hear of the existence there of any of interest or importance. The reefs make very little show on the surface as a rule; in many cases, indeed, the whole back of the reef, or lodes, has been removed during the mining operations of the old native miners, whose workings were on a rather large scale considering the means they had at command. Much also of the surface is masked by scrub jungle or by a thick coating of soil, often a local black humus. The reefs are so very inconspicuous that I have not attempted to show them on the map. Their run is north and south with a few degrees variation either east or west. The hade of the reefs is westerly in most cases, as far as they have been tested by the shafts sunk. The angle they make with the horizon is a very high one, on the average not less than from 85° to 87°. Much has been said about the reefs in the Kolar not being true fissure veins, but I was unable to find any good reason for promulgating this view, and several mining engineers of high standing and great experience, as Messrs. Bell Davies, Raynor St. Stephen, and other practical miners well acquainted with the locality, have no hesitation about calling them "fissure veins" or "lodes." The quartz composing the reefs is a bluish or greyish-black diaphanous or semi-diaphanous rock, and remarkably free from sulphides (pyrites, galena, &c.) of any kind. The gold found is very pure and of good color. Several washings of crushed vein stuff were made in my presence at the Urigam and Kolar mines with really satisfactory results, the quantity of gold obtained being very appreciable. The samples operated on were not picked ones.

Position of the mines.

The principal new mines now in progress form a line stretching from south to north on the eastern side of an imaginary axis drawn along the centre of the synclinal fold, and this line coincides with that followed by the "old men," many of whose abandoned workings are being extended to greater depth than they had the power of attaining to without steam pumping machinery. The principal mines opened along this line of country are the Madras, Mysore reefs, Great Southern of Mysore, Kolar, Mysore, Uregam (Woorigun), Nandidrug and Balaghat mines, belonging to the several companies bearing those names. On the west side of the axis only one company, the Kaisar-i-Hind, had started workings at the time of my visit. The five most northerly mines of the eastern group appeared to be working on extensions of the same set of reefs.

Intrusive trap rocks.

Numerous large dykes of dioritic trap are met with traversing the gneissic rocks of this region. One set of them runs north and south with a variation of about 5° east or west. The other runs nearly east and west. The presence of these dykes will offer formidable obstacles to the mining works in some places, and it will probably be found that the intrusion of these great igneous masses has added considerably to the metamorphism of the schistose beds along the lines they traverse. As already mentioned the schists are most highly altered along the central axis of the synclinal fold, and the largest of the north and south dykes shows a very little to the east of the synclinal axis.

Stratigraphical relations of the several schist bands.

The Kolar schistose band is the only one as to the exact stratigraphical relation of which to the granitoid gneiss any positively conclusive evidence had been obtained; but there is reason to believe that at least three of the schistose bands to the westward of it, *viz.*, those of Sundur, near Bellary, of Dambal—Chiknayakanhalli, and of Dharwar—Shimoga are similarly superimposed on the granitoid rocks. Whether the superposition is a conformable or an unconformable one, is a point that has yet to be determined by further investigation; at the Kolar gold-field, however, the relation between the schistose synclinal and the underlying granite gneiss appears to be one of distinct conformity. The Hospet end of the Sundur schist band certainly presents every appearance of being the acute extremity of a synclinal basin. The south-eastern extension of this band is as yet unknown, but there is good reason to expect a considerable extension of it to the south-eastward of Bellary.

The remarkable length of the Dambal—Chiknayakanhalli and Dharwar—Shimoga bands precludes the idea that they can be each a simple synclinal fold, rather may they be expected to prove a succession of synclinals and anticlinal in echelon, with their contact boundaries not unfrequently coinciding with faults. The geographical position of these great bands confirms and amplifies the evidences to the fact which I specially pointed out in my memoir on the East Coast from latitude 15° N., northward to Masulipatam—Memoirs, Geological Survey of India, volume XVI—that the Peninsula of India had been greatly affected by tremendous lateral forces acting mainly from east to west and thrusting up the gneissic rocks into huge folds (*l. c*, p. 39). These great foldings have undergone extensive denudation, and the softer schistose beds especially have been entirely removed from large tracts of country which they must have formerly covered, if any of the bands now remaining really represent (as they in all probability do) portions of once continuous formations.

The schistose bands having only been mapped at different points their general width, as shown on the annexed sketch map, is only hypothetical, and it is very possible that at intermediate points they may either spread out or narrow considerably. Their relation to the schistose gneissics of the Carnatic Proper has yet to be made clear, and it is not at all unlikely that a third sub-division will have to be recognized in the crystalline rocks of South India—a sub-division which will include the rocks of a character intermediate between the typically schistose rocks and the typically granitoid rocks of Mysore and the South Mahratta country, namely, the massive gneissics of the Carnatic in which the ferruginous beds are magnetic, not hæmatitic.

Record of borings *for* coal *at* Beddadánol, *Godávari district, in 1874, by* WILLIAM KING, D.SC., *Deputy Superintendent (Madras), Geological Surveys, India. (With a plan.)*

The outcrop of Barákar (coal-measure) rocks in the neighbourhood of the small village of Beddadánol is about five square miles in extent, situated on the head-waters of a large feeder of the Yerra-Kalwa, some 38 miles west-north-west of Rájamandri, and about four miles from the boundary of the Nizam's dominions near Ashraopet. The nearest large village, Gunnapawarum, lies a mile and a half to the south. It is the most southern known outcrop of the coal-measures in India; but very probably they extend further south beneath the covering barren members of the same Gondwána system, which reach in a straggling fashion to as far as Golapilli, 15 miles west of Ellore.

The Beddadánol outcrop was first detected by Mr. Blanford in 1871 (*supra*, vol. v., p. 24), and notices of the field were subsequently given by me (*supra*, vols. v. and vi., and Memoirs, vol. xviii., p. 247). The detailed record of the trial borings will be of use in future exploration; the work was executed by Mr. Vanstavern.

From T. VANSTAVERN, Esq., Executive Engineer, Public Works Department, to MAJOR J. BEATTY, R.E., District Engineer, Godavery District,—dated Dowlaishweram, 16th June 1874, No. 65.

I HAVE the honour to submit the following report on the boring operations at Beddadánol during this last season :—

The work was commenced in the latter part of February last. On arrival at Beddadánol a place was selected and boring commenced.

BORE-HOLE No. 1.—LEVEL 94 FEET. SUB-SOIL 16 FEET.

After going down to this depth came to sand and water. I tried to force down the piping and to get the sand up with valve bucket; but this utterly failing I was, for the want of sand tools, obliged to abandon this hole and to commence another.

2nd.—SECTION OF No. 2 BORE-HOLE.—LEVEL 100 B. M.

Sandstone	89·00
Dark clay	17·00
Shale with coal	11·00
Dark clay	1·00
Light clay	27·11
Black clay	7·00
Sandstone	4·00
Dark clay	4·3
Black clay	5·6
Sandstone	6·6
Light clay (soft)	33·9
Dark clay	6·0
Brown clay	8·0
TOTAL	229·11

water struck in this hole at 5 feet depth close to the main stream.

This hole was commenced in the out-crop of the bed of sandstone in the hopes of it being a solid bed of sandstone overlaying coal; but after getting down the full depth bored, the hole began to give considerable trouble by caving in at the soft clay; half a day was generally spent clearing out the hole before any further boring could be gone on with, and at last it became so bad that the hole could not be cleared out; it had to be abandoned, and another hole commenced.

3rd.—No. 3 BORE-HOLE —LEVEL 105 FEET.

Water struck at 44 feet deep.

Sub-soil	1·0
Gravel	2·5
Sandstone	93·7
White clay	10·0
Sandstone	39·0
Conglomerate	2·0
Sandstone	12·0
Light clay	10·0
Sandstone	51·
Dark clay	5·6
Light clay	3·0
Dark clay	2·0
Sandstone	13·0
Clay	3·0
Sandstone	8·6
Sandstone with pyrites	10·0
Argillaceous sandstone	10·0
TOTAL	274·0

The 10 feet of iron pyrites cost several days' labour to cut through.

During the working in this hole some delay occurred, owing to the breaking of the winch frames which had to be repaired before any more work could be done.

This hole when deep also commenced to give trouble by caving in.

One day it did so when the valve bucket was down, and after four hours' labour was got up with it and the rods twisted. Another attempt was made to clean out the hole, but after a whole day's work was unsuccessful and obliged to abandon it.

In this hole no shale or coal was struck, although I expected that the shale of No. 2 would have shown itself, for this reason shale in No. 2 must be of very little extent to the eastward, is either a pocket, or the sandstone beds dip more than they show at the surface. To the westward of No. 2 no borings have been sunk and no certain idea can be formed at surface of the extent of the bed of shale, but it may be naturally supposed to run in that direction according to the dip of the sandstone and the shale in No. 2 may represent the outrun.

4th.—No. 4 Bore-hole.—Level 107.

Water struck at 65 feet depth.

Surface soil	1·6
Light clay	18·6
Conglomerate	0·6
Sandstone	47·0
Dark clay	3·0
Light clay	2·6
Red clay	19·0
Sandstone	2·0
Dark clay	13·7
Sandstone	3·5
Dark clay	12·6
Sandstone	6·0
Dark clay	21·0
Sandstone	1·6
Dark clay	7·6
Shale and coal	0·8
Dark clay	1·0
Black clay	7·0
Dark clay	2·6
Clay with mineral charcoal	5·6
Iron Pyrites	3·0
Hard sandstone	4·4
Black clay and shale	4·10
Coal	4·6
Dark clay	6·6
Hard stone	0·8

This gave also continual trouble by caving in, and took daily some hours to clean out before work could be commenced.

Coal has been struck in this hole; in appearance it is poor and could be anything but the outrun to the east. Further borings would be required to find the extent of the bed, and probably it would improve as is generally the case in these beds.

By the depth it lays at it has apparently no connection with No. 2.

The dark and black clays in this hole have all carboniferous matter in them, apparently plants or leaves, but being so cut up with the boring tools, it is impossible to determine them.

The last 8 inches in this hole took some four days' boring; the rock is very hard, and apparently metamorphous, but I have no means of testing it; a sample accompanies the clays.

From W. King, Esq., Deputy Superintendent of the Geological Survey of India, to the Honourable D. F. Carmichael, Acting Chief Secretary to Government, Madras,—dated Calcutta, 12th August 1874, No. 21.

5. The result of the coal explorations so far is that four seams of coal, or carbonaceous shale, have been struck in the field; one of these in bore-hole No. 2, and three in No. 4. There is a little discrepancy between the lists of strata in the bore-holes given in

Mr. Vanstavern's report and the specimens now sent up; but practically this does not alter the case. There are four specimens marked as *coal*, while, in the bore-hole lists, they are given as "shale with coal" in No. 2, "shale and coal," "clay with mineral charcoal" and "coal" in No. 4.

6. The four specimens of coal are all dull and earthy; that from the 4½ feet seam being the best looking, the others are more or less associated with clay and shale. Nevertheless the fact remains that there are four seams with coal in them, thick and poor coal in one, and thin and poorer coal in the others. It is possible that each of these seams may be greatly better in quality aud thickness in other parts of the field.

7. On a private application of Mr. Vanstavern, after I had heard that the specimens had been sent down to Madras, he sent me a sample of the lower two feet of the thick seam, which is evidently the better part of the deposit. An assay of this sample, made in the Survey laboratory by my colleague Mr. Tween, gives the following result:—

Carbon	16·4
Volatile	30·6
Ash	53·0
	100·0
As a coke	
Carbon	22·5
Ash	77·5
	100·0

8. At first sight the large percentage of volatile matter indicates a fair gas coal, but Mr. Tween tells me that there must be from 12 to 14 per cent. of moisture included in the volatile element. Thus it is emphatically a poor coal.

9. The samples forwarded from Madras are evidently inferior to that assayed, and are not therefore worth examination.

10. The remaining specimens forwarded are clays, a piece of the "sandstone with pyrites," and the rock of the "last cut" in No. 4 bore-hole which, owing to its hardness, practically stopped Mr. Vanstavern, and led him to look on it as a metamorphic rock, that is, that he had reached the floor of the field. Among the clays there is a very dark grey variety, which my friend Mr. Hughes of the Geological Survey recognises as similar to some of the fire-clays he has met with in the Raniganj coal-fields.

11. The rock of the "last cut" is not really so hard as it appears to be in the bore-hole when examined as a hand specimen, and it is easily pounded down to a fine powder of clayey constitution, without any appreciable calcareous matter in it. It is a rock of brownish-green colour, consisting of minute granules of darker substance in a pale green paste, the surface being roughened with these granules; and it is evidently a form of volcanic rock approaching perlite, or perhaps an ashbed. In its mottled appearance it is not unlike "snake stone" or "Water of Ayr stone." It is impossible to say whether it is associated naturally with the sandstones and clays, *i. e.*, as a boulder, or as an intercalated bed. This can only be found out by further borings, or, as is advisable, by a further attempt to pierce it in No. 4.

I do not think it can be considered as a rock forming the floor of the coal-field.

12. As previously stated in my paper on this field, the beds are all, on the average, dipping about 10° west-south-west except in the northern part of the field, where they are N. W., thus having a strike N. N. W.—S. S. E, and then N. E., and, therefore, had the bore-holes been put down in lines starting from the eastern side of the field and going

westward, we should gradually have got through the whole thickness of strata. The work was not commenced till very late in the season, and thus I wished, if possible, to get at coal at once. With this intention, and in the hope that the river itself might hide strata in which were seams of coal, I instructed Mr. Vanstavern to begin on the river near the village. The first bore-hole was a failure. No. 2 bore-hole was then put down and carbonaceous shale was got in it; but it had to be stopped owing to falling in of clays and want of piping. To get lower than we had done in No. 2 it was necessary to look eastward, but no suitable place showed until in the nullah to the north of the village, and this would be in strata much below those examined in No. 2. Still an idea could be got from No. 3 of the lowest beds in this line, and as is shown in the list, they are all sandstones of good thickness with fewer and thinner clays than in the other bore-holes, but without the slightest trace of coal.

13. By these two bore-holes—in the line from No. 2 to No. 3—we know of 229 feet in No. 2, below which there is an unexamined thickness of strata of about 250 feet, when the beds at the top of No. 3 bore-hole ought to be reached. That is, supposing that the lie of the strata is tolerably uniform over the field and that there is not an irregular floor.

14. On seeing that No. 3 was not likely to produce any favourable result, and that it was becoming a troublesome hole, I suggested that a convenient spot should be selected to the south of the village in the nullah on that side, as I thought we should here be in the continuation of the unexamined beds between No. 2 and No. 3, and it is in these that the three other seams have been found. In other words, I expect that these seams would be found at very nearly the additional depth below the 229 feet of No. 2. This would of course be at an inconvenient depth for boring, more especially as the extent of the seams can be ascertained by other short holes.

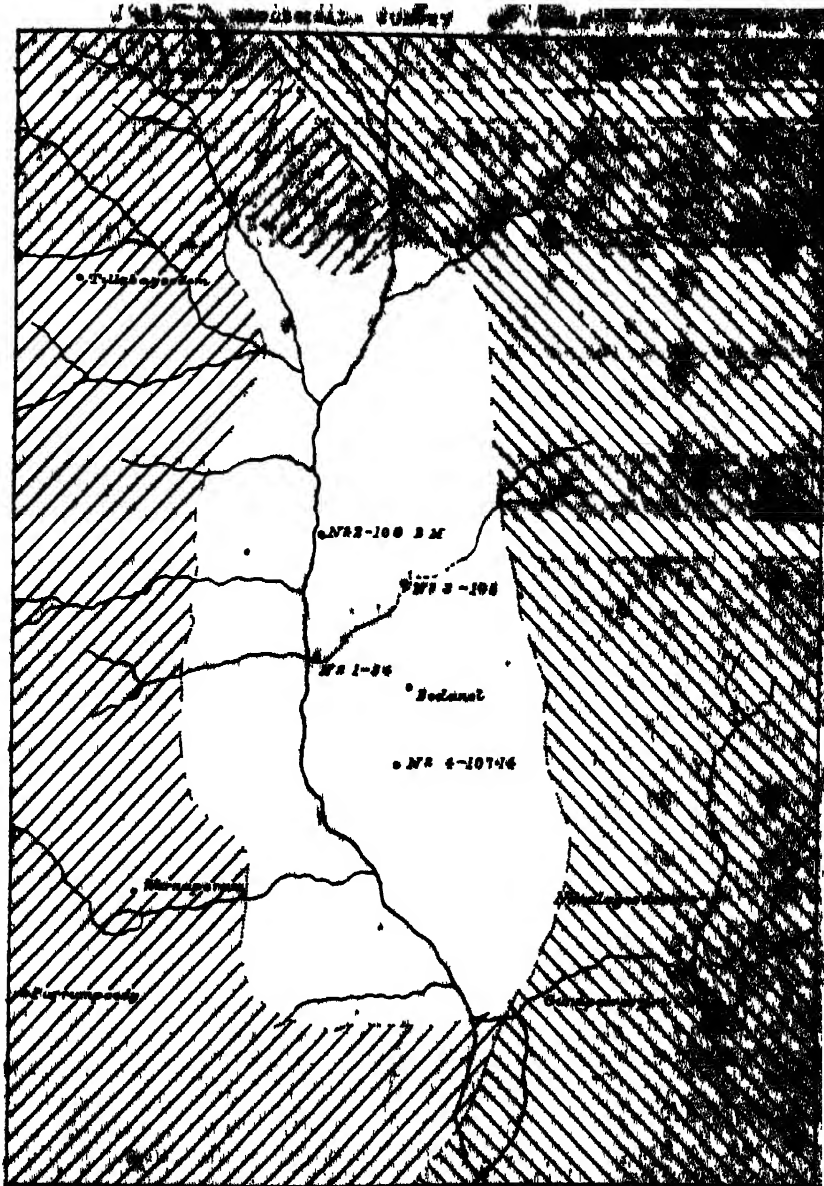
15. Bore-hole No. 4 has not yet told all that may be made from it if the hard "ash" rock can only be pierced, for there are still some few feet to be got through before reaching beds corresponding to those at the surface of No. 3. Otherwise, another bore-hole should be put down about 400 yards back, *i.e.*, eastward and in the nullah south of the village.

16. I examined the different streams in the field even more closely than hitherto, and saw that the strata seem to lie in a very regular succession at angles varying from 10° to 15°; the dip, if any thing, becoming easier to the westward of the main stream, as also to the N. W., where the beds are nearly flat and with fewer undulations, so that the thickness of the whole field is much more than I at first concluded. There is thus more room for seams over the western half of the field. Indeed, from this greater thickness I am more inclined to expect a greater extension of the coal-measures under the Kamthi sandstones of Namiapolliam to the westward.

17. With regard to the coal in these measures, that now known to exist is on the eastern edge of the field, and it is reasonable to expect that the seams go on thickening with the strata, or that there are more seams.

18. There is about the same area of coal-measures exposed on the western side of the main stream, but the strata here are all higher than those on the east side. No borings have been put down in these upper beds, but they are just as promising in their characters as those below. Indeed, my colleagues who have worked in the other coal-fields of India have observed that seams are more prevalent in upper beds of the Barákars. The lie of the strata on the right bank of the river is also somewhat easier, so that if coal be found on this side the probability is that the trial borings will not vary much in depth as they are carried out further west or north-west.

19. It is, however, very premature as yet to try and reckon on what may be from the few indications obtained so far; for where, as is evidently the case here, there is only an outlying patch of the coal-measures, not an area left so much by denudation as merely the



BEDANOL COAL FIELD, BORING SITES.

Barakar

Scale 1 inch = 1 Miles.

filling in of a detached basin by a formation which was existent only in an attenuated condition, the occurrence of coal to a greater or lesser extent in each patch is a question attended with a great deal of uncertainty. There may be only a few seams as at Kamarum, or many seams as at Singareny in the Nizam's Dominions; or seams hardly any of which are continuous in different bore-holes as in the British field below Dumagudium.

20. The main and first thing to be done now is to continue No. 4 bore-hole, or to sink a fresh one to the eastward of that, as suggested above, and then to work down the nullah to the main stream; after that, the nullah on the other side of the field higher up the main stream, and coming from Namiapolliam, ought to be tried. This latter examination would tell if the poor seam in No. 2 hole is of any extent. It would certainly be premature to try any of the ground south of the tributary nullah near bore-hole No. 4 until more is known concerning the succession of the seams now struck.

21. In conclusion, it is necessary, from my views of the relations of the strata in this field, to remark on two passages in the Government Order, No. 1953 of the 21st July. It is therein stated:—"But the very slight indication of shale and coal found about 30 feet above the coal deposit in No. 4 may be analogous to that of No. 2, with which it agrees in the strata immediately over and underlying." My observations do not bear out this analogy; for unless unforeseen accidents—of which there is no indication in the adjacent nullah sections—have interfered with the normal position of the strata, everything seems to lead to the conclusion that the beds of No. 4 are lower than those of No. 2. Besides, if the upper seam in No. 4 be analogous to that of No. 2, it is difficult to account for the non-occurrence of the 4½ feet seam in No. 2, which is the deeper bore-hole.

22. There is then the further statement that "the conclusion arrived at to bore next season to the south and west seems a correct one." On this point it will be seen from this letter that I do not advocate such a procedure, but to keep for the present rather to the north and north-west as soon as the west side of the field is taken up. But, apart from this, I would respectfully submit that a conclusion as to the future sites of bore-holes ought more properly to be based on the recommendation of the Geologist, as long as he is not absolved from the office of advising, as to the possible *locale* of the coal. In this, however, it is not for a moment implied that there is any likelihood of a difference of opinion between Mr. Vanstavern and myself on the mode of pursuing the work; on the contrary, I have to thank him for having always so willingly co-operated with me.

Note on the supposed occurrence of coal *on the* Kistna, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

The Records of the Geological Survey of India would be incomplete without some mention of the reputed discovery of coal near Jaggayapet, in the Kistna District of Madras, that has so often within the last thirty years been urged upon the notice of Government by General Applegath. It has this year been brought forward again with unabated confidence; and the following Note upon the question was drawn up for the information of the Government of Madras. It affords a curious contemporary illustration of science *in excelsis*.

1. I have the honour to acknowledge receipt of your letter No. 230 E., dated 13th June 1882, forwarding for remark a letter, dated the 19th May, from Major-General F. Applegath, on the subject of his alleged discoveries of coal in the Kistna District. I had already noticed in the newspapers, English and

Indian, the revival of the Kistna coal question, and I am glad of this opportunity of submitting some remarks thereon for the consideration of the Right Honourable the Governor of Madras.

2. General Applegath must believe that the patience of the Madras Government is inexhaustible, and well he may; for surely, since the dawn of science, no claimant to discovery has anywhere met with so much indulgence as he has from his Indian masters. Time after time has he found favour and encouragement, after repeated demonstration by most competent authority that his assertions and promises were baseless, and after repeated failures on his part, with liberal aid of public money, skilled labour and appliances, to verify his assertions. It is no wonder that he should now again come forward in bolder form than ever. I must confess that, to the qualified and responsible ministers and advisers of Government in these matters, any further countenance to such pretensions would be "heart-breaking."

3. I will presently give an abstract and analysis of this remarkable case: it is desirable, first, to clear the question of irrelevant matter, and to fix attention upon what has been the mainstay of so much discussion. It is not to be believed that the Government or the public would, for a moment, place the judgment of one so completely uninstructed in such matters as General Applegath, that the rocks of the Palnád belonged, in whole or in part, to the already established coal-formation of the Peninsula, in competition with that of the Geological Survey, that they were all of Transition or Lower Vindhyan age; the two being as widely separated stratigraphically as are the Jurassic and the Silurian systems of Europe. The "fossils" sent by the General in support of his contention were not fossils at all; and his rock specimens scarcely bore any resemblance to the standards to which he referred them. The occurrence of coal in those older rocks would, of course, be an independent question; and although a very extensive survey of them in that very field and in other parts of India had revealed no trace of a coal-measure group, there would still remain the possibility of a local deposit. The question is thus brought within very definite limits of fact, and it would never have taken shape but for General Applegath's assertion, that at a particular spot, within 20 feet of the surface, he had once upon a time quarried coal and burned it.

4. To any one whose ideas on the subject were not altogether in the air, nothing could be simpler than a complete verification of such a statement. It is practically impossible that several tons of coal could be extracted and leave no trace to tell the tale; yet with every appliance of tools and skilled labour, funds and time, General Applegath has never again been able to produce an ounce of any substance that would support combustion. He has, however, never ceased to reiterate his assertion; and his confidence has imposed upon others no better informed than himself; the strong wish for the realization of his assurance being on both sides the efficient motive of assent. It is a striking instance, and an instructive caution, upon the persuasive influence of unflinching testimony in a credible witness, for no one that I know of has ever cast a suspicion upon General Applegath's truthfulness.

5. In its successive orders giving sanction and encouragement to General

Applegath's explorations, ignoring its own previous adverse decisions upon the case, Government did not, of course, give reasons for so doing; but we may safely take these to be the same as those that guide public opinion in the matter. In a Calcutta daily paper of the 28th March last, *à propos* of General Applegath's recent manifesto, it is said: "This case of coal in the Kistna District is probably another instance in which practical men have been ahead of the geological theorists." Nothing but the diffusion of knowledge can remove the popular delusion that is revealed in this sentence; but as it contains the only approach to direct argument that I have seen, it is of practical importance to point out that the instance referred to as parallel is of a wholly different nature. It refers to the discovery of the coal measures in the north of England by deep sinking through newer over-lying formations. The writer of the article implies that the geologists were false prophets on that occasion, and no doubt the pit-sinkers were practical men; but in the Indian case the facts are all above board; the rocks at the surface in the Palnád are immensely older than any known coal-measures, and the only evidence to warrant any outlay on exploration is General Applegath's assertion that he once quarried coal there within a few feet of the surface. Surely a practical man would require the General to make good his assertion before starting on, what would otherwise be, a wild-goose chase.

6. The acts and arguments referred to imply more or less of credence in General Applegath's frequent animadversions upon what he takes to be the carelessness, the contradictions and the obstructiveness of the Geological Survey. I do not care to exhibit the ridiculous misunderstandings upon which such remarks have been based. Too much time has already been wasted over this tiresome business, and I have shown that the whole question turns upon a simple matter of fact. The supposition that a body of professional men could be so infatuated as to pooh-pooh a project founded on so circumstantial a basis, which, if true, must inevitably be presently substantiated, is only further evidence of the hazy view taken of the conditions. Until this ground had been visited, the Survey gave every encouragement to the investigation. It has been said that Dr. Oldham's visit to the Palnád, in company with General Applegath and others, was made in a perfunctory manner. But this, again, is unfair. Dr. Oldham went to see all that General Applegath had to show regarding the existence of coal, and finding no vestige of real evidence, it would have been foolish of him to sit by while a boring was made in slate, on the chance of unearthing a coal-seam. Dr. Oldham officially and publicly (Madras G.O., No. 1125 of 27th April 1868) denied the statement that anything like "burnt shale" or "burnt outcrops," or "a substance rich enough to support combustion," had been seen. Since then, and before it, General Applegath has had ample means and leisure given him to make good the statement that he had once burnt coal extracted from the site in question, but all his endeavours have been in vain.

7. As it is not a ghost story, some intelligible explanation of the mystery must be forthcoming. The most likely one was suggested by Dr. Oldham, that to please their master, the natives had put some real coal in the hole and produced it for his satisfaction. A hoax of this kind was shortly after successfully practised upon Dr. Oldham himself, and all the officials concerned, in

the famous case of the Midnapur borings.[1] In the Kistna case, however, there was hardly room for this without culpable blindness on the part of the victim, for the excavation is said to have been a shallow drift, and accordingly General Applegath repudiated the "insinuation," averring that he had himself conducted and seen the operations, and repeating his statement in the following emphatic and expanded form :—" I adhere to my assertion that I have actually quarried and burnt coal in large quantities on the spot, as much as eight or ten tons "—(Madras G. O., No. 606 of 7th March 1868.) There thus remains a cut-and-dry choice between a physical anomaly (amounting to impossibility) and a case of mental delusion, such as is unhappily of too common occurrence in history. In going through the documents for the present, I hope final disposal of the case, I have been greatly struck by the fact that General Applegath's assurance becomes clearer and stronger and larger as the event recedes in time.

8. The oldest papers I have on the subject are a manuscript map and two sections, with a brief list, all signed " F. Applegath, Lieutenant, Assistant Civil Engineer," and dated " Camp Moogetalah, 18th December 1850." The map is entitled " Plan of the Marble fields near Jaggiapetta on the Kistna and Pallair Rivers," and, with the sections, it is coloured geologically (after a fashion). There are five pits marked on the plan, and the list annexed is headed " Description of the pits, &c., that have been sunk in searching for coal." One of these pits is at the very place assigned for the coal discovery, on the left bank of the Pallair, about half a mile above its confluence with the Kistna. This pit is figured on one of the sections to the full depth ever said to have been attained there, and the only legend is—" shaft 20 feet through slate, with a soft material below, thickness unknown." In the List the same is described as—" Pit No. 3, shaft sunk 20 feet through slate, small but distinct traces of vegetable deposit at the lowest excavation, and a soft, white deposit at the bottom of the shaft, thickness unknown." In these original documents the word " coal" only appears in the title of the List as a desideratum; the rock in the pit being correctly noted as " slate." The date usually assigned by General Applegath for his discovery of coal is 1851, so it might be surmised that these notes are anterior, and not to the point; it seems not improbable, however, that they represent the total result of his operations before going on leave, when he reported his discovery to the Court of Directors, and, before leaving, to the Madras Government; for the map is endorsed " Lieutenant Applegath's supposed coal sites; from Walter Elliot, Madras C. S., August 1851." If this be the case, there would be no escape from the

[1] An European convict was employed as brace-headman on a boring for water in the Central Jail at Midnapore. The place stands on a spread of laterite connected with the old alluvium occurring as a fringe between the Gangetic delta and the upland of gneissic rocks. At a depth of 148 feet coal was reported to occur for a thickness of more than two feet. Samples were sent by the Executive Engineer to Calcutta to Dr. Oldham, who pronounced the coal to be good, and indicated sites for other borings to test the extent and the lie of the supposed seam. In these, also, the coal was brought up from appropriate depths. This took some time; meanwhile the convict, having completed his term, was awarded with a post of some trust in charge of the work. As matters were coming to a crisis and more extensive operations about to be taken up to work the coal, the ex-convict took the occasion of an advance of cash to disappear from the scene of his exploit, and no trace of him could be discovered. The imposition was then brought to light.

judgment that the quarrying and burning of coal must take rank as a myth: so important a piece of evidence would certainly not have been left out in the contemporaneous account. No doubt many tons of the black slate were excavated, and nothing is more likely than that some pieces of it were put into a good camp fire, after which ordeal they would bear a tolerable resemblance to ash, and such may have been the small basis of fact which has grown so portentously. The samples of this stuff deposited at the Madras Museum would excusably have been thrown out as rubbish.

9. The next evidence tends to confirm this view. It consists, again, of a coloured map and sections, with a report entitled—"Captain F. Applegath's description of the geological strata on the north bank of the Kistna," dated Madras, 28th of April 1861. In this the same shaft, apparently, is referred to (here marked as No. 1), thus:—"An attempt was made some years ago to sink No. 1 shaft for coal through the red shale in the southern part of these fields; the red colour appears to be superficial, for, at a depth of 10 or 15 feet, the colour changes from red to greenish grey, and blue, and sometimes black. * * * * This occurred in 1851." There is no specific mention of the horizontal drift, 17 deep, from which, in later accounts, the coal is said to have been obtained, but I here find, for the first time, a notice of this circumstance, and only in a casual way, as a by-gone event, and as secondary to what is considered more important observation, thus:—"The limestones, shales, sandstones, and the fossils found, all tend to confirm and strengthen the belief that these rocks of the Kistna are of the age of the Indian coal-bearing strata; moreover, the bituminous rock that I quarried and burnt contained upwards of 30 per cent. of carbonaceous matter." The authority for this determination is not given, but it at least fixes a maximum value for the "coal" of later statements. At all events, in a concluding summary of the case, this point is left out of count, and the whole question stated as problematical—"All that has hitherto been done has been at private expense, and thus, for eleven years, the suggestion of the probability or the reality of there being coal on the Kistna has been a source of anxiety of mind on one side, with incredulity on the other, and therefore it is a question still to be decided on its own merits; at least, I think, there is presumptive evidence of the fact of the existence of coal on the Kistna, for, in Bengal, the arenaceous shale with fibre-like impressions of plants is coal-bearing, also blue shale, and at Nagpore the greenish-grey shale overlies bituminous shale and coal, the same in Bengal."

10. After this, the enquiry took a more official form. In August 1866, Major Applegath submitted a memorial to Government, soliciting aid for further exploration, again urging the identity of the rocks with the Indian coal-measures, but the "myth" now takes distinct shape, thus:—"I here most distinctly state that, on the occasion of one of my visits to the locality I have described, on the Pálár and Kistna Rivers, I burnt, in several large heaps, the coal I had quarried, and that I even carried some and burnt it in the Sherehomedpettah Bungalow compound. I believe that not less than nine or ten tons were quarried and burnt, and that while burning it gave out great light and intense heat, and, except that it was much heavier, it was not unlike the Torbane hill mineral." Due mention is, however, made, of failure to re-discover that combustible rock:—"Having once quarried and

burnt the coal on the Kistna, I am not discouraged by my recent failure to reach the coal, and this dear-bought experience will prove invaluable in the next attempt. I am confident that coal exists there, its extent and thickness it is impossible at present to estimate." This application was referred to Dr. Oldham for opinion. Dr. Oldham deprecated boring until some fair evidence of the probability of coal being found should be established, remarking that "it would appear only reasonable to expect that Major Applegath should be able to show where he had quarried the coal, and the expenditure of very few rupees, not one-hundredth part of what borings would cost, would in a few hours prove the existence or non-existence of any bed of coal." He offers to arrange for a geologist to visit the ground in company with Major Applegath. This visit took place in January 1868, Dr. Oldham going himself. He was accompanied by Colonel Applegath, Mr. Stuart, Assistant Collector of the district, and Mr. C. Oldham, who had been for some time engaged upon the examination of the same rocks further to the south. In the report of his observations Dr. Oldham remarked: "After this careful examination, I regret to report that, in my opinion, there is no ground for any hopes whatever of coal being found within this area. The rocks are all of types well known, and covering a very large area of the Cuddapah and Kurnool Districts, and in no respect that I could see do they, in this part of the country, offer any feature which would induce one to suppose that there was a greater probability of coal being found here than at a thousand other localities within the very extensive area over which similar rocks extend to the south, and at some one of which it would, I think, certainly have become known did it exist." As no more of the so-called "coal" or combustible rock could be found, the suggestion is made that it may have originally been provided for the occasion. In General Order No. 590, dated 5th March 1868, the Government of Madras accepted this report as proving, beyond all doubt, the non-existence of coal in the valley of the Kistna.

11. At this juncture the episode of the Midnapore coal adventure occurred, raising sanguine hopes that coal might be found anywhere. In April 1870 a memorandum was forwarded by the Madras Government, urging further search in that Presidency, saying there seemed no reason why coal should not be found beneath any of the vast tracts of laterite in Southern India as well as at Midnapore. Dr. Oldham (being then under the deception as to coal at Midnapore) gave a reasonable answer (June 1870), explaining the different conditions—how all the measures of the Raniganj coal-field passed eastwards under the alluvium of the Ganges delta, and how impossible it was for any one to say how far they might or might not there spread out to north and south on the buried slopes of the gneissic upland; that there were no analogous circumstances in the lateritic regions of Madras, &c. But all this was as moon shine to the promoters of such a scheme, and a profound distrust of geological insight remained; nor was faith restored when the fiasco of the coal at Midnapore was made known, for had not the geologists been taken in just as others.

12. General Applegath was not slow to take advantage of these favourable conditions. In July 1870 he applied for a grant of money and a detachment of Sappers and Miners, equipped with boring and blasting tools for exploration in the

Kistna District. The geological affinities of the rocks were not referred to, the one tempting assurance given being that he had once seen coal quarried and burnt in large quantities in that district. Approval and sanction were at once accorded (G. O., No. 1024, 15th August 1870). When the two months allowed were nearly expired, an extension of time and an additional grant were asked for on the following plea:—"The Sappers have to this date been employed in opening out the rocks; and as some of the pits are now 25 and 30 feet deep, I am enabled to offer an opinion on the probability of finding coal in this district; and, after a very careful comparison of the Kistna rocks with all the other coal-bearing districts in India, I am most decidedly of opinion that their representatives are found in this locality—I do not mean on the surface of the ground, but that they have been excavated by the Sappers in the present investigation. I have, therefore, to express my firm belief in the existence of coal here, and the prospect of obtaining it very shortly from one or more of the pits now being made by the Sappers and Miners under my charge." The request was at once granted (G. O., No. 42, 11th January 1871). The total results of the explorations were submitted in a paper headed "Conclusions," dated 16th February 1871. There is no allusion even to the non-discovery of anything combustible, or to the sanguine hopes so recently expressed regarding coal. There is nothing in the paper but a rambling discussion of a collection of the rocks, attempting to identify them with the Indian coal-measures. Colonel Applegath was thanked for his exertions, and the specimens were ordered to be sent to the Geological Department for opinion (G. O., No. 336, 15th March 1871). Dr. Oldham's memorandum (12th May 1871) on these specimens gave a complete demonstration that Colonel Applegath had no rational idea of what he attempted to describe, and pointed out the utter waste of investigations so conducted.

13. In this interval the survey of the great basin of the Cuddapah and Kurnool rocks, of which the Palnád forms the northern extremity, was completed by M. M. King and Foote, as published in Volume VIII, pt. 1, of the Memoirs (June 1872). There had been some discussion as to whether some beds in the Palnád should be placed in the Kurnool or in the Cuddapah series of transition rocks; but no possibility presented itself of any belonging to the Gondwana system, although, of course, the Surveyors were fully informed of the coal controversy. This transition basin is the area which General Applegath now presents as likely to become the largest coal-field in India. From there Mr. King went northwards, and at once identified the coal-measure rocks in the Singareni field, and found coal there.

14. Nothing daunted, and absolutely impervious to professional criticism, General Applegath, in September 1873, submitted to Government another map and description of the Jaggayapet District, with suggestions for further borings for coal, and remarks on some diamond strata in the neighbourhood. It is simply a repetition of all the old fallacies and assertions,—giving names to the imaginary fossils, and impossible correlations to the rocks, with heroic composure, as if nothing had ever been said to the contrary. The maps and notes were ordered to be printed and circulated; twelve copies to be furnished to Colonel Applegath, with the best thanks of Government for the valuable

information they afford (G. O., No. 1020, 30th September 1873).[1] I happened at the time to be officiating for Dr. Oldham, and I was called upon by the Government of India for any remarks I might have to offer. My answer may not have been forwarded to Madras. In March 1874 I submitted to Government a detailed note on this map by Mr. Foote, who had surveyed that ground; his remarks would satisfy any one having some knowledge of geology. In April 1874 I had the pleasure of an interview with Colonel Applegath, on his way through Calcutta, prior to leaving India. He informed me there was a proposal on foot for a renewed search for coal in the Palnád by the Public Works Department; and as he expressed himself satisfied in every way with this arrangement, I got him to mark on his own map the spots at which he most desired borings to be made. In the hope of putting an end to this tiresome craze, I forwarded these indications to Government, recommending that the borings should be undertaken when Mr. Vanstavern could be spared from the borings in the Bedanól coal-field in the Godávari district. Mr. Vanstavern's account of his operations was submitted by the Superintending Engineer, Major Hasted, R.E., in whose report the following remarks occur :—"The instructions conveyed have been fully carried out, and even more borings than were directed have been made. Mr. Vanstavern remarks that 'no coal-bearing rocks nor outcrops of coal or any combustible matter was met with,' and expresses his opinion that 'by the nature of the rocks there certainly cannot be any coal.' It is with some regret that I am obliged to express my entire concurrence in Mr. Vanstavern's views, but the explorations have been so complete, that I feel sure if coal existed at all in these places, some signs of it must have been discovered. The borings have been made as close as possible to the pits dug by Colonel Applegath, and in every instance have been sunk considerably below the bottom of the pits; in addition to this, Mr. Vanstavern, at my request, cleared out the horizontal shaft in which it was understood Colonel Applegath found something resembling coal which he was able to burn, but nothing was met with except shale. I am puzzled to know what the substance was which Colonel Applegath supposed to be coal, but some of the stuff brought up from the borings, which is described as 'black clay shale with graphite' and 'dark brown clay' might, it appeared to me, be supposed to be taken from the immediate neighbourhood of coal. My own opinion is of little value, but I am anxious to state that I watched the operations with much interest, and was rather predisposed to think Colonel Applegath's views were correct. I believe I may say that, up to a certain point, Mr. Vanstavern seemed to agree with me; but after several borings had been made, and the country round explored, he informed me that he had little or no hope of finding coal." On this report, His Excellency the Governor in Council declared himself to be quite satisfied as to the completeness of the investigation carried out for the exploration of Colonel Applegath's supposed coal-field on the Kistna (Madras G. O., No. 761, 18th March 1875).

15. Not so, however, General Applegath; as, indeed, might have been expected from the obduracy he had formerly exhibited in the face of previous ample refutations by himself and others. In the letter under reply and the annexed

[1] See *supra*, Vol. VII, p. 3.

statements made before the Society of Arts,[1] as well as in the newspapers, General Applegath protests against the insufficiency of this examination, and declares his position as a discoverer of coal in Madras to be unshaken. His words imply that these trials were made by the Survey Department, but that is an error; no Survey Officer went near them; they were made by officers of the Public Works Department, who declare their initial persuasion to have been favourable to his view. As already stated, I do not notice General Applegath's frequent and now recurring misrepresentations of quotations from the reports of the Survey, as they evidently proceed from his complete ignorance of the subject; but it would be impossible to make a like excuse for his misrepresentation of the simple facts of these trials. In a letter to the *Madras Mail* he says: "I was in England at the time these borings were made, and so I could not have selected the sites." This is something more than a *suggestio falsi;* the indication of sites for borings by marks on the map of ground well known to the marker is a completely recognised act of professional responsibility He objects that at one of his localities three borings were made, only to depths of 7, 8, and 23 feet; but he omits to mention that all three came upon metamorphic rock He objects that all the places he had recommended were not explored this would indeed have been a trial of patience, and a culpable waste of time after the principal places, those selected by himself, had proved complete failures; one of these indeed should have sufficed, the one where coal was said to have been once extracted. Four borings were made at this spot, all deeper than any of the original pits; but what is most important, the actual drift from which the supposed coal was obtained was opened out and explored, but no vestige of combustible matter was found. The General offers no remark upon this collapse. I have no doubt whatever that a jury of practical men would give an unanimous verdict of 'proven' against General Applegath's coal in the Palnád.

16. One very interesting observation in General Applegath's remarks to the Society of Arts remains to be noticed, as it throws much light upon the mystery that attaches to this romance of coal on the Kistna. I pointed out at the beginning that the General's *cheval de bataille* throughout the whole contention has been his assertion that, once upon a time, he had quarried and burned coal on the spot where now it has been shown no coal exists. But for this unmistakable evidence he would never have been listened to; in fact, he did not obtain a practical hearing until he mounted this charger in full panoply. In the original contemporary documents (1850) there is no mention of this discovery; in the unofficial report of ten years later, it is casually quoted as a combustible rock having 30 per cent. of carbonaceous matter; but in the official memorial of 1866 it has become coal giving out great light and intense heat. This is the familiar process of genesis of the myth; and such I take General Applegath's coal to be. In paragraph 7 of his "Record of the Kistna Coal" (from the Journal of the Society of Arts) there is another very neat and instructive example of the same kind of performance; the old steed having broken down, a fresh one is trotted out from the depôt of memory. Of the black clay from Mr. Vanstavern's boring

[1] April 28th, 1882, on the occasion of Professor V. Ball's lecture on the Mineral Resources of India.

No. 6, it is remarked: "I believe that this black stuff is coal that has been partially burnt, as it has the appearance of coke, or burnt coal, and, under a magnifying glass, it presents every appearance of coke, or burnt coal, and, when ignited, *burns like a coke fire.* It may even be a natural bed of coke." The italics are mine. I am not aware that any of this clay was sent to General Applegath, but that would not signify; it is assumed to be the same as some black stuff he had once thrown into a fire and beheld to become red hot. The General evidently "walks by faith:" in a letter to the *Overland Mail,* refuting the conclusive evidence of Mr. Vanstavern's borings, he remarks: "Quite on the contrary, the very important question of coal or no coal near Juggyapettah may (D. V.), I believe will, be definitely settled in the affirmative, if a little trouble can now be taken by the authorities in Madras." It would be sacrilegious to gainsay this final appeal to Providence, but I think the game is played out.[1]

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[1] The Government of Madras (G. O., 15th August 1882, No. 2096 W., Public Works) has decided not to re-open the question.

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October 7th, 1882.

RECORDS

OF THE

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OF

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VOL. XVI.

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CONTENTS.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1883. [February.

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1882.

South Rewah: Umaria coal field.

Mr. Hughes.

The most important result of the past season's work has been the proving of the new coal field of Umaria at the west end of the South Rewah Gondwána basin, within 34 miles of Katni Station on the East Indian Railway. This field was mentioned in the last annual report, and Mr. Hughes had given a notice of it, in the Records for 1881 (Vol. XIV, pt. 4). The actual area of exposed coal measures is small (about 5 square miles), in an angle between the gneissic rocks and the great spread of newer Gondwána sandstone to the north-east. The outcrop of coal had been known for many years, but its appearance at the surface was not promising. All this area had been surveyed in 1872 by Mr. Hacket, without distinguishing the true coal measures; but, from what I had seen of the ground (in March 1869), on a preliminary inspection between Raniganj and Jabalpur, I was aware that further examination would be necessary before anything could be published. Mr. Hughes' success was then no chance find; he recognised a difference between the Umaria sandstone and that of the adjoining area, and he had close search made for fossils, from the evidence of which there was no longer any doubt of these rocks being on the horizon of the regular coal measures. He then at once marked sites for trial borings; and these were carried out with very commendable expedition by the local authorities. The results as to the extent, thickness, and quality of the coal are very promising. A notice of these borings was given by Mr. Hughes in the Records for August last. Railway surveys are now being made for a line from Katni to the coal field.

The field thus opened to enterprise is very extensive. Umaria is the nearest possible source of coal for the North-Western Provinces; and immediately east of it lies the immense coal field of Sohágpur, which district is also rich in agricultural produce and the natural entrepôt for the surrounding forest tracts. From Sohágpur southwards lies the least difficult line of communication between northern and southern India, into the plains of Chhattisgarh, leading down the Máhánadi valley to Cuttack, and up it over the plateau of Bastar to Vizagapatam.

Not the least important result of this new opening is the opportunity it gives for successful iron manufacture. I know of no spot in India where there is such an abundant supply of a variety of first class iron ores as in the neighbourhood of Katni. Much of the lime now used in Calcutta comes from Katni, and other requisites will probably be forthcoming, if the coal fulfils our expectations.

Mr. Hughes extended his survey of the Sohágpur coal field eastwards into Sirgujah. He reports in very encouraging terms of the services rendered by Sub-Assistant Hira Lal.

SHAHPUR COAL BORINGS.

In the annual report for 1877 (Rec. XI, p. 7) a notice was given of the explorations for coal in the Sátpura region carried on by the Central Provinces Government under my advice; and the concluding operations of those trials are given at page 97 of the Records for 1879 (Vol. XII). Most of those trials were near the northern edge of the basin close to the Narbada valley, and four of them were in interior valleys. In every case the object was to find the coal measures themselves, for the borings all started in rocks known to be of later formation, and in one case only, that close to Mohpáni, was there an outcrop of the coal measures anywhere near. None of them were successful; and it was then pointed out that the nearest ground where there was a direct prospect of coal was in the Shahpur field on the south side of the basin. The coal outcrops there had been reported on separately by three officers of the Survey (in 1859, 1866, and 1875), but none held out any promise of valuable seams. The latest of these surveys was by me (published with a map in Vol. VIII of the Records), and I then marked three sites for borings in different parts of the field, in view of future experimental exploration. These trials were taken up in February 1881, by the Public Works Department of the Central Provinces, and the last of them was closed on the 11th of October 1882 under my instructions. Two of them were made to a depth of 400 feet, and the third to 539 feet. They all passed through several coaly seams, with some thin bands of coal; but none were of sufficient promise to recommend the sinking of a trial shaft. I believe that all the coal-bearing measures were passed through in each boring, but the seams are even poorer than at their outcrops. The coal prospects in the Sátpura basin are thus for the present reduced (besides the Mohpáni mines) to the Pench valley field, of which Mr. Blanford gave a very encouraging report in 1866 (Records, Vol. XV, pt. 2, 1882). This field has naturally been left to the last on account of its comparative inaccessibility; but the engineering difficulties to be overcome are nothing like so great as those on the new Indore and Bhopal State Railways, and a line from Itarsi up the Tawa valley to the Pench would be in every respect the most favourable for crossing the Sátpura range between the Nárbada valley and Nágpur. Such a line would pass along the Shahpur coal field, and might lead to a further exploration of those measures.

ASSAM: DARANGGIRI COAL FIELD. *Mr. LaTouche.*

The cretaceous coal field of Daranggiri in the Gáro hills, reported on by Mr. LaTouche (Records, Vol. XV, pt. 3) during last season, proved quite as good as was expected; the quantity is very considerable and the quality very serviceable; but if the company now engaged in opening out the coal fields of Upper Assam achieves anything like the service it proposes, it would scarcely pay to work the much inferior coal of Daranggiri. Mr. LaTouche is now engaged in tracing the coal of the Jaintia hills eastwards, with reference to a project for a railway through North Cachar.

SOUTHERN INDIA. *Mr. Foote.*

Mr. Foote was engaged in the districts of Mádura and Tinnevelly, principally in completing his map of the coastal region, and joining this work with that of Mr. King in Travancore. The principal features of the ground had been examined in previous seasons, so there is nothing particular to be noticed. A detailed account of this large area will be published during the current year. Late in the season Mr. Foote made a traverse across part of the Mysore gold fields, an account of which is published in the Records for November.

BILLA-SURGAM CAVES.

An object of much interest has long been awaiting investigation in the Madras Presidency, in the osseous cave-deposits of the Karnúl district. This interest is more than geological; at least, for a large section of the intelligent public early pre-historic man is their only link with geological studies. India has been a focus of great expectation in this matter, upon the assumed evolutional principle that the natural conditions in tropical or sub-tropical regions were most favourable for organic development, and because the earliest known civilisations had arisen in such regions. Nine years ago, in 1873, there was a momentary confirmation of those hopes, when an undoubtedly manufactured stone implement was found by Mr Hacket in the beds of the Narbada valley containing remains of extinct varieties of mammals, deposits which had been considered by Falkoner and Dr. Oldham on palæontological grounds as of pliocene age. This 'find' (the word 'discovery' might well be reserved for the fruits of mental effort) gave fresh interest to the question of age of the Narbada osseous gravels, and from a purely geological (stratigraphical) discussion I gave reasons (Records, Vol. VI, pt. 3) showing that they are probably of late post-tertiary time—a view that has since been adopted. At the same time I ventured to impugn the *á priori* doctrine as to the birth-place of mankind, suggesting that, although the remains of the most man-like monkey might be found in tropical regions, we might rather expect to find traces of the most monkey-like man where now the least monkey-like men are found to flourish, taking mind as the characteristic. The early civilised peoples of tropical countries were probably not indigenous.

The cave-test has still to be applied. Some of the most interesting early human remains have been found in cave-deposits; and under the inspiration of the doctrine aforesaid, a party was got up a couple of years ago at private expense to explore caves in Borneo; but the success has not fulfilled the expectations. Apart the human question altogether (the special urgency of which is now rather popular than scientific), great biological interest attaches to any rich deposit of mammalian remains, and I am strongly urged to take some steps to have the Karnúl caves explored, for there can be no doubt of the information regarding them as announced by the distinguished pioneer of geology in Southern India, Captain Newbold, F.R.S. I have never failed to appreciate the importance of this matter, though I am aware of an impression abroad that I disregard palæontological interests, for which supposition there can be no better foundation than that I have never cared to dabble in matters that can only be profitably handled by experts. In October 1876, within six months of my taking charge of the Survey, I made official inquiries regarding the Billa-Surgam caves, as no notice was made of their whereabouts in the memoir and map descriptive of the Kadapa and Karnúl basin by Messrs. King and Foote. I intended that Mr. Lydekker should visit the caves and report with a view to further exploration. The Madras famine supervened, and no later opportunity offered without too great a sacrifice of current work.

Mr. Blanford makes conspicuous mention of these caves in the Manual of the Geology of India (page 381). Captain Newbold in 1844 described them as situated in latitude 15° 25′, longitude 78° 15′, which should be, as taken from a map of that date (Indian Atlas, Sheet No. 76, of 1842), about 7 miles to north-by-west from Banaganpilli. In the answer I received (dated 10th January 1877) from the Collector of Karnúl, this officer says :—" There is no place near Banaganpilli which goes by the name of Billa-Surgam and noted for any caves containing fossil stones. There is, however, a village called Bilum, 7 miles south-east of Owk in the Koilkuntla taluk, containing some caves, but the Deputy Collector who inspected them says they contain only slate stones." This position would be about 12 miles to south-by-west of Banaganpilli. Both these spots are in the Jamalmadgu limestone, of Messrs. King and Foote's classification, described by Newbold as the 'diamond limestone.'

It is most unlikely that an error of 18 miles would occur in his description of the position, but the coincidence of the similar name and the caves gives a strong presumption that Bilum is Newbold's locality, and that there is a printer's error in the statement of the latitude. He describes the mouths of the caves as from 46 to 60 feet high, falling rapidly to passages which it is necessary to traverse on hands and knees. This obscurity as to the occurrence of the caves offers some explanation of the omission of any mention of them in the published description of that ground; but I would notice the circumstance as an illustration of the condition of our work in India, the imperative object being to furnish in the first instance and as soon as possible a good general sketch of the geology of India. Had our geologists taken in 'cave-hunting' and the like, the map and manual published in 1879 might have appeared about the year 3000. There is, however, no failure of apprehension as to the supreme importance to advanced science of more detailed researches, and I hope to find an early opportunity for the exploration of the Billa-Surgam caves.

KHANDESH; CRETACEOUS: *Mr. Bose.*

Mr. Bose's second season's work in this ground has not added much to the fossil evidence upon which he indicated a correlation of the upper beds with the threefold division of the cretaceous rocks of Southern India, relegating the underlying Nimár sandstone to a lower cretaceous horizon, as mentioned in last year's annual report; nor is there any fresh observation to disturb that suggested arrangement. He gives some interesting facts showing the association of the Lameta beds with agglomerates of the trappean period; and his microscopic examination of the traps themselves has thrown new light upon the constitution of some of their subordinate varieties. When Mr. Bose was sent to that ground, it was hoped (without authority) that the new maps containing the north-western and south-western extensions of the cretaceous deposits in the Rewa-Kánta country would be available, so that the geological region might be described in one memoir. As there is even now no near prospect of those topographical maps being completed, Mr. Bose's work will be published up to date.

RAJPUTANA; *Mr. Hacket.*

In extension of his previous survey, Mr. Hacket took up work in the wilder parts of the Arvali range in southern Meywar, but in the end of January he was warned by the Political Agent that it would not be safe for him to continue in that part of the country on account of the unquiet state of the Bhils. Mr. Hacket employed the rest of the season very usefully in examining some intricate features along the Vindyan boundary to the north-east of Neemuch.

Sub-Assistant Kishen Singh has mapped a large area of the plateau of Málwa trap and Vindhyans about and north of Goona. The boundaries are, I believe, sufficiently approximate for those formations, and for present purposes; but little or no information is given regarding the rock features upon which a description of the area could be given.

KATTYWAR; *Mr. Fedden.*

Mr. Fedden surveyed a large area along the coastal region, from Bhávnagar to Madhapur, mostly of trap and post-tertiary rocks, with a remnant of tertiary beds on the western sea-margin. A few fossils were obtained from these at Piram (Perim) Island. The ossiferous conglomerates of this well-known locality are the highest beds of the section; but Mr. Fedden considers them to be closely associated with the deposits containing marine shells forming the adjoining coast, which he correlates with the Gáj horizon (of Sind). At Gogha, a little north of Piram, a boring was once made in these strata to a depth of 355 feet, stiff blue clay being the prevailing rock in the lower portion.

THE NORTH-WEST FRONTIER; *Mr. Blanford.*

The principal object of Mr. Blanford's work in the field season 1881-82 was to endeavour to trace northward the well-marked series of tertiary rocks found in Sind, and to follow the continuation of them, if possible, into the Punjab, where there is not the same clue to classification in the presence of marine beds above the eocene.

Before taking up this work, Mr. Blanford was called upon to report again upon the coal deposits to the west of Sibi; so he marched by the Bolán pass to Quetta, examining the coal seams of Mach on the road. From Quetta to Sibi he returned by the Harnai route, and visited the Sharag (or Sharigh) coal locality. From Sibi he skirted the western boundary of the Bhugti Hills, and then marched from Jacobabad to Harrand in the Punjab, through the heart of the Bhugti country. From Harrand he proceeded northward along the eastern flank of the

Sulimán range, to some distance north of Dera Ghási Khán. Here, in the middle of February, a severe attack of fever and liver compelled him to leave the field, and he shortly afterwards returned to Calcutta and was obliged to go to Europe on medical certificate.

A note, containing the results of Mr. Blanford's examination of the coal seams at Mach and Sharag was published in Part 3 of the Records for 1882. He considers the quality of the coal fair, but the quantity is insufficient for commercial purposes. The other results of his season's observations have been, besides making some important alterations in Mr. Griesbach's work about Quetta, to effect a preliminary exploration of the country from Quetta to Dera Ghási Khán, and to show that the post-eocene marine deposits of Sind do not continue north to the Punjab border. One of the unfossiliferous groups, however,—the Upper Nari,—is apparently persistent, and the uppermost system, Siwálik or Manchar, can be sub-divided, so that it is practicable to classify the rocks to a certain extent. It was found that the main chain of the Sulimán is composed of hard whitish sandstones, apparently cretaceous, overlying limestones and limestone-shales, with a few fossils belonging to the same system.

Had the work not been interrupted by illness near Dera Ghási Khán, Mr. Blanford would only have been able to examine the Sulimán range for about 30 miles further north. The whole of the area examined was beyond the British frontier; but, whereas, up to a certain point, a little north of that reached, access was practicable with the aid of the district officers and a small escort, further north the country is inhabited by Afghans, and is consequently inaccessible to Europeans. It may, consequently, be considered that the greater portion of the gap between Sind and the Punjab has been bridged over, so far as is practicable.

Some interesting fossils, mammalian and molluscan, were obtained from Lower Siwalik beds, at localities discovered by Captain Vicary nearly 40 years ago in the Bhugti hills. Mr. Blanford's descriptive memoir, with a map, will be published shortly.

MIDDLE HIMALAYA: *Mr. Griesbach.*

On the termination of his short leave in England Mr. Griesbach obtained permission to visit some places on the Continent, in order to see what process would be best for the reproduction of his views of Himalayan sections; but chiefly that he might examine certain foreign collections of fossils from the Himalaya and other parts of Asia for comparison with his own collection. On both points his trip was very serviceable; the collections made in Armenia by Staatsrath von Abich proved especially interesting, as having close relation to the fossils from certain zones in the Himalayan sections. Owing to some unforeseen official delays Mr. Griesbach was a little late in returning to India, which caused him much discomfort in having to cross the outer ranges of mountains after the rains had set in. With the Bhoteas of the frontier Mr. Griesbach experienced the usual difficulties in making arrangements for transport in the high uninhabited regions where his work principally lies. All his endeavours were in this way frustrated to cross the Mana pass, so he had to cover all the ground he could reach in that direction from the Niti pass, and then move to Nilang, where he had better success in making excursions northwards. The season was so far advanced that the Tibetan guards had left their stations beyond the passes, so this obstruction was removed, but the cold was intense.

MANIPUR: *Mr. Oldham.*

Mr. Oldham accomplished all that could be expected from his excursion with the Manipur-Burma Boundary Commission, having made a complete traverse of the main range into the great alluvial and tertiary basin of the Ningthi (? Namtonai of older maps) or Chindwin (Kyen-dwen), which seems to be a principal tributary of the Irrawadi. If there is any disappointment in the result, the credit (or discredit) of it must be set down to mistaken imagination, and I must confess to having made that mistake. I had, I may say, hoped that the Aracan Yoma of Mr. Theobald's Pegu Report would expand northwards as it approached the Himalayan massif; and that a deeper rock-section would be exposed, with perhaps a core of crystalline rocks, having their roots, even in outcrop, confluent with those of the great Himalayan elevation. The fact is just the reverse. Here, too, no fossils were found; but the rocks are with great probability identifiable with those 400 miles to the south, even to the serpentinous intrusive masses. Mr. Oldham supplemented his east-west traverse by marching from Manipur northward to Kohima in the Nága Hills, returning by the Assam Valley, and he found that newer tertiary rocks encroach more and more towards the axis of the range; so that it seems as if the older rocks may soon be altogether suppressed in that direction. It thus appears that this range is altogether a secondary one, a mere fender of the great Malayan crystalline axis. I need hardly add that I am more satisfied than if my prognostic had proved correct. Mr. Oldham's report has been ready since July, but there is some delay in procuring a map of the topographical survey of the new ground.

Publications.—Two parts of Volume XIX of the Memoirs were published during the year. The first is a description, with numerous illustrations, of the Cachar earthquake of 1869. The descriptive part was written shortly after the event by the late Dr. Oldham, from observations made by himself on the spot. The discussion of the data was supplied, and the whole edited, by Mr. R. D. Oldham. Part 2 is a descriptive catalogue of the thermal springs of India, and Part 3 (now in the Press) is a descriptive catalogue of Indian earthquakes. These also were compiled by Dr. Oldham; the data have now been revised and illustrative maps prepared by Mr. R. D. Oldham. These publications form a good starting point for seismological observation in India, preparations for which on a small scale are now in hand. Several other memoirs are well advanced towards publication, by Mr. Blanford, on the country between Quetta and Dera-Ghází-Khán; by Mr. Foote on a large area between Trichinopoli and Cape Comorin; and by Mr. Oldham on parts of Manipur and the Nága Hills.

Volume XV of the Records for 1882 contains numerous (28) papers of more or less practical importance or of scientific interest.

Five fasciculi of the Palæontologia Indica were brought out during the year:—Part 1, Vol. IV, of the Gondwána Flora by Dr. Feistmantel gives a description of the fossil-flora of the south Rewah basin. Mr. Lydekker describes the Siwálik and Narbada Equidæ in Vol. II, part 3 of the Tertiary Vertebrata series. Dr. Waagen's first fasciculus on the Brachiopoda of the Productus-limestone in the Salt-range is but a small instalment of this section of his work; but I have already received 30 plates of the sequel. The Brachiopoda form the most numerous and most intricate portion of this group of fossils, and the exhaustive study Dr. Waagen is giving of them will, I have no doubt, be gratefully acknowledged by all palæontologists. Two fasciculi on the fossil Echinoidea of Sind are contributed by Dr. Martin Duncan and Mr. Percy Sladen, to whom the Survey is greatly indebted for their voluntary assistance in this important branch of palæontological research.

Museum.—Of all field work in progress, the corresponding collections of specimens have been kept up to date. A full descriptive catalogue of the systematic series of minerals by Mr. Mallet is nearly through the Press.

Library.—The additions to the library were 1,461 volumes or parts of Volumes; 665 by purchase and 796 by donation or exchange. The titles of all these books as received are published regularly in the Quarterly Records. I think I can promise that the catalogue will be in print by the end of the present year. The preparation of it can only be carried on in the intervals of current work.

Mining Records.—One mining plan was received during the year, from the Raniganj Coal Association.

Seismological Observations.—Proposals have been made before now to establish seismometers in certain parts of India that are subject to comparatively frequent earthquakes. A chief difficulty has been, and must continue to be, to find competent and trustworthy observers at the suitable places. A small expenditure for the purpose has now been sanctioned, enough to set up some simple seismometers at a few stations in north-east Bengal and Assam where meteorological stations are already established, through which agency it is hoped some observations may be secured.

Personnel.—Mr. Blanford was obliged to take sick leave to Europe on the 25th of April, and, under medical advice, he has since been compelled to retire from the service, as no longer able to endure the exposure and fatigue required of the field geologist in India. After 27 years of so arduous a life this result is not surprising; he joined his appointment in India on the 1st of October 1855. From the beginning of his service, Mr. Blanford took a leading part in the work of the Survey; his report on the Talchir coal field is the first paper in our Memoirs, which have now extended to 19 volumes, containing numerous contributions from him. Besides his regular geological labours Mr. Blanford has done much work for the zoology of India, on which he is now a leading authority. He was twice deputed on missions out of India,—with the army to Abyssinia, and with the Seistan Boundary Commission to Persia. Of his researches in both countries he published a full account. He was twice (in 1878 and 1879) elected President of the Asiatic Society of Bengal, an honour never previously conferred on an officer of his standing. So long ago as 1874, he was elected (at his first nomination) a Fellow of the Royal Society, which is the highest non-official distinction an

Englishman can require. In 1876, Dr. Oldham, on retirement, recommended Mr. Blanford to be his successor as Superintendent of the Geological Survey of India; of this he was only deprived by a small matter of seniority, and in recognition of his high claims Government rewarded him with a special personal remuneration above the pay of his appointment. Personally, as well as professionally, Mr. Blanford's departure will be much regretted by his colleagues in the Survey.

Mr. King was absent on furlough for the whole year. Mr. Wynne was obliged to take successive extensions of sick leave, and is still absent. Mr. Hughes obtained six months' leave on urgent private affairs on the 8th June, which has been extended in England for three months. Mr. Hacket left on furlough for two years on the 20th November. Mr. Lydekker was granted six months' leave on urgent private affairs from the 2nd March, and subsequently by the Secretary of State an extension for one year without pay. Privilege leave for various periods was granted: Mr. Mallet 42 days, Dr. Feistmantel 40 days, and Mr. Medlicott 3 months.

H. B. MEDLICOTT,

Superintendent, Geological Survey of India.

CALCUTTA,
The 23rd of January 1883.

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1882.

AMSTERDAM.—Netherlands Colonial Department.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
„ Royal Natural History Society, Netherlands.
BELFAST.—Natural History Society.
BERLIN.—German Geological Society.
„ Royal Prussian Academy of Science.
BOLOGNA.—Academy of Sciences.
BOMBAY.—Meteorological Department, Western India.
BOSTON.—American Academy of Arts and Sciences.
„ Society of Natural History.
BRESLAU.—Silesian Society of Natural History.
BRISTOL.—Bristol Museum.
„ „ Naturalists' Society.
BRUSSELS.—Geological Survey of Belgium.
„ Royal Geographical Society of Belgium.
„ Royal Malacological Society.
„ Royal Natural History Museum of Belgium.
BUDAPEST.—Geological Institute, Hungary.
BUFFALO.—Society of Natural Sciences.
CAEN.—Linnean Society of Normandy.

CALCUTTA.—Agricultural and Horticultural Society.
,, Asiatic Society of Bengal.
,, Marine Survey.
,, Meteorological Department, Government of India.
CAMBRIDGE (MASS.).—Museum of Comparative Zoology.
CASSEL.—Society of Natural History.
CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
,, L'Association Géodésique Internationale Commission de la Norvège.
COPENHAGEN.—Royal Danish Academy.
DRESDEN.—Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
,, Royal Dublin Society.
,, Royal Irish Academy.
EDINBURGH.—Royal Scottish Society of Arts.
,, Royal Society of Edinburgh.
,, Signet Library.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Geological Society.
,, Philosophical Society.
GOTTINGEN.—Royal Society.
HALLE.—Natural History Society.
HARRISBURG.—Geological Survey of Pennsylvania.
LAUSANNE.—Vandois Society of Natural Science.
LIEGE.—Geological Society of Belgium.
LONDON.—Geological Society.
,, Iron and Steel Institute.
,, Linnean Society.
,, Royal Asiatic Society.
,, Royal Geographical Society.
,, Royal Institute of Great Britain.
,, Royal Society.
,, Society of Arts.
,, Zoological Society.
LYONS.—Museum of Natural Science.
MADISON.—Superintendent of Public Property.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
MELBOURNE.—Mining Department, Victoria.
,, Royal Society of Victoria.
MILAN.—Italian Society of Natural Science.
,, Royal Institute of Lombardy.
MONTREAL.—Geological Survey of Canada.
MOSCOW.—Imperial Society of Naturalists.
NAGPUR.—Nagpur Museum.

NEUCHATEL.—Society of Natural Sciences.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy.
,, American Journal of Science.
PARIS.—Academy of Sciences.
,, Geological Society of France.
,, Indo-Chinese Society.
,, Mining Department.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.
PISA.—Society of Natural Sciences, Tuscany.
ROME.—Royal Geological Commission of Italy.
,, Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
SAINT PETERSBURG.—Imperial Academy of Sciences.
,, Imperial Russian Mineralogical Society.
SALEM (MASS.)—American Association for the Advancement of Science.
,, Essex Institute.
SHANGHAI.—North China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
SYDNEY.—Australian Museum.
,, Department of Mines, New South Wales.
,, Royal Society of New South Wales.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Science.
VENICE.—Royal Institute of Science, &c.
VIENNA.—Imperial Academy of Sciences.
,, Imperial Geological Institute.
WASHINGTON.—Smithsonian Institute.
,, United States Geographical Survey west of the 100th Meridian.
WELLINGTON.—New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
,, German Naturalists' Society.

The Governments of Bombay, Madras, North-Western Provinces and Oudh and the Punjab.

Chief Commissioners of Assam, British Burma, Central Provinces, and Coorg.

The Commissioner of Inland Customs.

The Residents at Hyderabad and Mysore.

The Surveyor General of India.

Departments of Finance and Commerce, Revenue and Agriculture, Foreign, Forest, and Home.

On the Genus Richthofenia, Kays, (Anomia Lawrenciana, Koninck,) *by* WILLIAM WAAGEN, PH.D., F.G.S. (*With 2 plates*).

IN one of the later numbers of the "Zeitschrift der Deutschen Geologischen Gesellschaft," M. E. Kayser publishes some notes on the fossils of the carboniferous limestone of Lo-ping in China, collected by Baron Richthofen, which fossils seem to be rather similar in type to those of the Productus-limestone of the Salt-range, the description of which is now in progress. He mentions one fossil in particular, the *Anomia Lawrenciana* of deKoninck, for which he proposes the generic denomination of *Richthofenia.*

M. Kayser regards this fossil as belonging to the Brachiopods, very likely somewhere near *Productus*, and this approximately agrees with what I considered it to be. I expressed this opinion in the last remarks appended to the third part of my "Salt-range Fossils" (p. 328); only I was at that time doubtful whether the fossil might not as well be considered a coral.

While preparing the description of the Brachiopods of the Salt-range Productus-limestone, I was obliged also to examine the *Anomia Lawrenciana* more in detail; and the result of this examination was so remarkable that I think it worth while to give a preliminary notice of this fossil, together with such figures as will be necessary to understand the description.

The fossil consists, as has been described already by deKoninck, of two valves, one larger and one smaller (Pl. II, *f.* 7, 8, 9). The larger valve is of a conical shape, with the apex fastened to some foreign body (Pl. I, *f.* 9). The smaller valve is flat, a little sunk into the larger one. The two valves articulate by a rather short straight hinge-line. This hinge-line, however, does not show in the outer appearance of the conical valve; it is only marked inside it. On both sides of the hinge-line, the smaller valve is cut out in a semi-circle to receive thickened parts of the shell of the larger valve. The outer side of the larger valve is rugose, provided with many concentric wrinkles, and bears a variable number of hollow, depressed, diverging, tortuous tubes, which, on the one hand, resemble the root-like appendages of some rugose corals, and, on the other, can be compared to the hollow spines of some *Producti.* The resemblance to the latter is chiefly striking because of the silky lustre of the shell-substance of which they are composed. On the whole, the shell of the fossil is dull when quite intact, and of a silky lustre when the outmost layer of the shell is worn off. Then also appears a very close punctation, similar to that occurring in the shell of *Productus*, which is barely visible to the naked eye.

The punctures are not all equal; some larger ones are disseminated irregularly between great numbers of smaller ones (Pl. I, *f.* 3). As has been mentioned above, the punctures appear only when the outermost layers of the shell are removed. The punctured part does not lie immediately below the epidermoidal shell-layer, but succeeds a very thin layer, also already exhibiting a silky lustre, which shows a very close vertical striation, and is composed of numerous very fine excavated lines (Pl. II, *f.* 8 *b*). Sometimes this striation is even visible on the outermost dull layer of the shell. Both these layers, the dull one as well as the striated one, are entirely lost in the greater number of specimens.

On the smaller (flat) valve the hollow tubes, which are so very characteristic of the larger valve, are altogether absent. When the shell-substance of this valve is perfectly preserved; it is strewn over with very numerous small papillæ which project slightly from the surface of the shell (Pl. II *f.* 9).

On its interior side this smaller valve bears a distinct, but not very high, median septum, which extends from near the margin opposite the hinge-line, to nearly the middle of the valve. Here, in most specimens, it is replaced by two parallel ridges, which in other specimens, however, are combined in one broader septum. On both sides of these ridges large, more or less rounded impressions appear, which are very strongly marked, and distinctly indented on the side nearest the hinge-line; on the side opposite to it they are less strongly marked, but seem to be also indented (Pl. I, *f.* 1*a*; Pl. II, *f.* 2). On the hinge-line itself there are, vertical to it, two short, thick and prominent parallel ridges, not dissimilar to hinge-teeth, which are, however, about equally high through their whole extent. They are not in connection with the median septum, but are separated from it by a smooth space. They do not protrude much above the hinge-line. On the whole, they might possibly be compared to the very developed cardinal process of the smaller valve of *Productus*, but the similarity is, in fact, only a very distant one. On both sides of these ridges not a trace of dental grooves can be observed. Neither the reniform bodies, which are such prominent features in the smaller valve of *Productus*, nor distinct dental grooves exist on the sides of the short ridges on the hinge-line. Near the outer margin of this smaller valve there are thorny processes, more or less numerous, directed towards the interior of the shell, similar to those seen in some *Producti* (Pl. II, *f.* 2).

Far more complicated is the structure of the larger valve. It consists of two different parts; the lower, from the apex of the valve up to about the middle of its height, being composed of very numerous narrow water-chambers, divided off by very thin shelly partitions, and the upper forming a large hollow for the reception of the animal. The partitions in the lower part of the shell are very irregular, exactly like the partitions existing in rugose corals. They are, on the whole, convex below, and concave above; not so, however, for their whole extent, as about in their middle they are bent upwards, forming something like a columella, such as exists in many corals. This formation of a columella is caused by the presence of three vertical septa (Pl. I, *f.* 2, 4, 5), which extend from the apex of the shell, through all the partitions, up to the body chamber. By these septa a vertical triangular space is divided off within the larger valve of this fossil, the base of the triangle being formed by the hinge-line, whilst its apex lies in the middle of the shell, where the three vertical septa, which converge towards this centre from both ends of the hinge-line, unite. The median of the three vertical septa extends from the centre towards the hinge-line, without, however, ever uniting with it. All the space between the vertical septa and the hinge-line is also filled up by shelly partitions.

The animal chamber (Pl. I, *f.* 1) is tolerably large; the bottom of it is, however, situated at very different levels. The triangular space marked off by the vertical septa is much more shallow than the remainder of the chamber; but the latter also is not even, as from the centre of the shell a rounded crest extends, forming a shallow saddle, to the wall opposite the hinge-line. On each side of this crest is a deep hollow which occupies the whole lateral parts of the body chamber. The whole bottom is covered by irregular tolerably minute grooving.

The three vertical septa project into the body chamber as three high upright plates, which converge towards the centre of the shell and are highest near this centre. Their upper margins are denticulate. They do not unite, but remain somewhat apart from each other. On the other side, between them and the hinge-line, there is an ascending plane, none of the plates thus reaching the hinge-line. Of these plates or septa, the median one is the highest. The two lateral are limited on their inner side by very deep narrow grooves; from the median one, on the contrary, on both sides start some low secondary septa, which show, on the whole, a pinnate arrangement. They disappear again, however, before reaching the grooves mentioned above.

The hinge-line is quite straight, and shows only in the middle a slight rounded sinuation for the reception of the two thick terminating branches of the median septum in the smaller valve. Not a trace of any kind of teeth for articulation with the smaller valve is observable.

The inside of the outer walls of the body chamber is provided at very irregular and unequal distances, with tolerably broad and sharp, but not very prominent vertical septa, some of which begin a short distance below the upper border of the chamber, and disappear before reaching the bottom, whilst others begin lower down and then reach down to the bottom of the chamber. The upper termination of each of them bears a round foramen, which forms the entrance to the hollow tubes which can be observed on the outer side of the shell and have been mentioned above (Pl. I, fig. 2). This foramen, however, does not pierce the wall directly, but the tube descends nearly vertically and appears only in the vicinity of the apex at the outer side of the shell.

All round the upper border of the animal-chamber a thickened margin can be observed, which has some similarity to a pallial impression (Pl. I, figs. 1, 8). Of muscular scars nothing can be observed either on the bottom or on the walls of the chamber.

The substance of the shell is of a very singular structure. It is composed in the larger conical valve of three layers. The outer one is very thin, dull and compact outside, and of a silky lustre inside, provided with the characteristic striation and punctation mentioned above. The median layer, the thickest of all, though very irregular in its thickness, is composed of approximately hemispherical cells, such as can be observed in many rugose corals when the radial septa have been obliterated (Pl. I, figs. 2, 7; Pl. II, figs. 1, 5). These cells are arranged in ascending radial rows, and are interrupted at intervals by perfectly straight, radial, very pointedly conical shelly parts (Pl. II, fig. 4) which require further explanation. They begin on the outer shell-layer with a slightly broader base, and extend, in a more or less ascending direction, towards the inner portions of the shell. They are not round but polygonal. All do not with their sharply pointed ends reach the innermost shell-layers; indeed, most of them stop about half way. Nor do all of them originate on the outer shell-layer, for some start from the wall of some cell in the median layer of the shell. They seem to be hollow and to form tubes, which apparently communicate with the larger pores, disseminated between the more minute punctation of the shell as described above; but I am not quite certain on these latter points. The hollow tubes which terminate in root-like processes as mentioned above penetrate this median part of the shell in a nearly vertical direction. The innermost layer of the shell is somewhat thicker than the outer one, but otherwise similar to it. The median and the outer layers of the shell fall off easily, and then internal casts of a strange description, which preserve the inner shell-layer, are produced (Pl. I, fig. 8).

In the flat smaller valve the median shell-layer is absent.

Under the microscope, with a magnifying power of 100 diameters and upwards, the whole shell can be seen to be composed of very thin lamellæ, which disunite for the formation of the cells and join together again in the outer layer of the shell. They are mostly vertical in the inner layer of the shell, bent nearly horizontal but irregularly outward in the median layer, and again vertically upward in the outer one.

Each lamella shows a very distinct striation vertical to its planes, caused apparently by prisms of which it is composed. These prisms are thus placed horizontally in the inner shell-layer from the inside of the shell to the outer, in the median layer vertically, and in the outer layer again horizontally.

Besides this striation fine canals can also be distinctly traced, which originate on the inner side of the shell and pierce the different lamellæ of which the shell is composed, causing thus the fine punctation of the inner shell-layer, similar to that occurring in *Productus*. The canals are, however, not simple, but distinctly and manifoldly ramified, and thus absolutely different from those occurring in *Productus*. They are more similar to the canals which pierce the shell of *Crania*. I do not think that these canals may be the work of boring *Thallophyta*. They seem to exhibit another character than the borings of those organisms. I shall, however, give detailed figures of these canals in my large work on the "Salt-range Fossils."

The fossil is gregarious in its occurrence in nature, and the individuals are often so closely packed together that the root-like appendages of one individual are fastened to the individuals around, but I never found two individuals entirely grown together.

These are the facts I have been able to ascertain relating to the structure of this fossil; it remains now to deduce from them the systematic position the fossil ought to occupy. As I have already formerly indicated, I was from the beginning doubtful whether the fossil ought rather to be considered a coral or a Brachiopod, and the views of palæontologists to whom I showed the specimens were quite equally divided between the two classes. Mons. Barrande, as well as Professor Valérin and Möller, were of opinion that this fossil was rather more related to the corals than to any other class of animals, whilst Professor Zittel and Professor Lindström seemed to be more in favour of the view which places it among the Brachiopods. The characters exhibited by the fossil are, indeed, of such a conflicting nature that it becomes extremely difficult to assign to it any place in the system.

In favour of the view which inclines to consider the fossil as a Brachiopod, the microscopic structure of the shell can be adduced above all. Its silky lustre is absolutely identical with that of the shell of *Productus*, though this lustre seems not to be effected in both cases by the same means. In the shell of *Productus* it is caused by obliquely ascending prisms, whilst in *Richthofenia* it depends apparently on the fine lamination of the shell as in *Placuna* or similar genera. Of great importance is the prismatic structure of the single laminæ of which the shell of *Richthofenia* is composed. Such a prismatic structure is, as far as I am aware, chiefly characteristic of molluscs or molluscoids. I certainly have not as yet observed this structure in corals. In *Calceola sandalina*, which seems the most kindred form among the corals, a microscopic section through the larger valve showed beautifully its construction of radial septa, but these septa exhibited all a granular, not a prismatic structure.

The punctation of the shell is also very similar to that of *Productus*, and so are the hollow root-like tubes which penetrate the shell-substance of the larger valve, and adhere to other bodies.

The smaller valve can also, on the whole, be very well compared to the same valve of *Productus*, though it remains doubtful whether the thick parallel ridges on the hinge-line of this valve in *Richthofenia* can at all be compared to a cardinal process, and whether the impressions on the valve can be taken as muscular impressions. Reniform bodies are most certainly absent.

Nevertheless, among all the Brachiopods the *Productidæ* are the only ones to which the genus *Richthofenia* might stand in any relation; other Brachiopods are certainly considerably less related to the present genus than the *Productidæ*.

But, though all the points indicated may be in favour of the Brachiopod nature of the present fossil, yet it cannot be denied that there exist also certain points of resemblance between *Richthofenia* and rugose corals. Any one who looks only for a moment at Pl. I, fig. 2, will be convinced of this similarity. The irregular partitions in the lower part of the larger valve; the columella-like part which is divided off by three vertical septa; these septa themselves, which can very well be compared with the primary and the two lateral septa of a rugose coral; the cellular structure of the shell; the septa-like ridges on the outer wall of the animal chambers which are in connection with the hollow canals which pierce the substance of the shell; and the tortuous tubes themselves into which the canals are prolonged on the outer side of the larger valve: all these characters remind one strongly of a rugose coral. There can be no doubt that on a first inspection, ignoring the silky lustre of the shell, one would far more likely be led to regard this fossil as a coral than as a Brachiopod.

There is, however, yet another character to be pointed out, which is even more conflicting than those hitherto adduced; this is the existence of something like a pallial impression round the upper margin of the larger valve, as figured in Pl. I, figs. 1*b* and 3*a*.

This character, as well as the very peculiar appearance of the partial cast as represented in Pl. I, fig. 8, and the longitudinal section, Pl. II, fig. 5, induced me to take yet another group of fossils into consideration for comparison; and these are the *Rudista* in a restricted sense, as defined by Stoliczka in his work on the cretaceous bivalves.

It is a very curious fact that with the *Rudista* the same difficulty prevailed as to their classification as with the present fossil. They had been considered by L. v. Buch as corals, by d'Orbigny as Brachiopods, and recently they are placed by most men of science in the bivalves.

The points of similarity between *Richthofenia* and the *Rudista*, chiefly *Hippurites*, are not very numerous, it is true. It is chiefly the section which may be compared. If we cut open a specimen of *Richthofenia* from the hinge-line to the opposite wall, so as just to touch the median vertical septum (Plate II, fig. 5), we get a figure very similar to that which we obtain when we cut through a *Hippurites* so as to touch the first columellar fold (the hinge-fold and the second columellar fold being left untouched), Plate II, fig. 10. The partitions presented are very similar in both cases. They are bent up in the middle to form a kind of columella, and are separated from the outer walls of the shell by a sharp line in both cases. It is due to this latter circumstance in both cases that the outer walls of the shell fall off easily, and that such strange partial internal casts are formed.

Another point of similarity consists in the direction of the prisms, of which the substance of the shell is composed. The *Rudista* differ from all the other groups of *Pelecypoda* in having the prisms of their outer shell arranged vertically, that is to say, longitudinally to the whole extension of the shell. Just the same is the case in the median shell layer of *Richthofenia*, as has been explained above.

A third point of similarity of great importance exists in the pallial impression, which is common to *Richthofenia* and the *Rudista*; and, finally, it is not quite certain that the sinuations of the large valve of *Richthofenia* on both sides of the hinge-line, which stand in so close a connection to the lateral vertical septa may not be regarded as the beginning of the infoldings of the shell, which are so very characteristic for the *Rudista*.

All these points of similarity between the *Rudista* and *Richthofenia* are important, as they are in connection with the most striking characters of both fossils; and it cannot as yet be positively denied that *Richthofenia* might be a predecessor of the *Rudista*. To say anything positive on this point is at present impossible. The distance in time between *Richthofenia*, which comes probably from the limits between the carboniferous and permian formations, and the *Rudista*, which are for the greater part upper cretaceous, is so enormous, and every connecting link is as yet absent, that a very close affinity between the palæozoic and the cretaceous forms cannot be expected, and thus it will only be possible to prove the connection between the present fossil and the *Rudista*, if futher members of such a developmental series should be discovered.

As the case now stands, it will probably be most prudent in accordance with the microscopic structure of the shell to consider the fossil as something like a

Brachiopod. As far as my opinion goes, I am convinced that *Richthofenia* is a member of a series, which, branching off somewhere from the rugose corals, has reached in *Richthofenia* a Brachiopod-like stage, and is going to terminate its career as a Pelecypod, as one of the *Rudista*. But opinion is nothing in science, and proofs are everything. I hope that these lines will give an impulse to the elucidation of the very obscure relations of the fossil which has been the object of this paper.

EXPLANATION OF PLATES.

PLATE I.

RICHTHOFENIA LAWRENCIANA, Kon. sp.

Fig. 1. Silicified specimen from the upper region of the Middle Productus-limestone of Musa Kheyl. 1*a*, view of the body chamber straight from above; 1*b*, the same slightly oblique from the front; 1*c*, interior side of the smaller valve of the same specimen: all natural size.

" 2. Natural section through a specimen from the coral beds of the Middle Productus-limestone of Virgal; the section being parallel to the hinge-line and just touching the termination of the three vertical septa. The cells in the walls of the animal chamber are not quite correctly represented.

" 3. Portion of the shell surface enlarged 4 to 5 times to show the punctation, in a specimen from the upper region of the Middle Productus-limestone of Musa Kheyl.

" 4. Fragmentary specimen from the Middle Productus-limestone of the Chittawán; 4*a*, natural section through the lower part of the animal chamber, showing the section of the three upright blades; 4*b*, artificial section, very oblique, lower down through the partitioned part of the shell, showing the vertical septa and the space that is limited off by them.

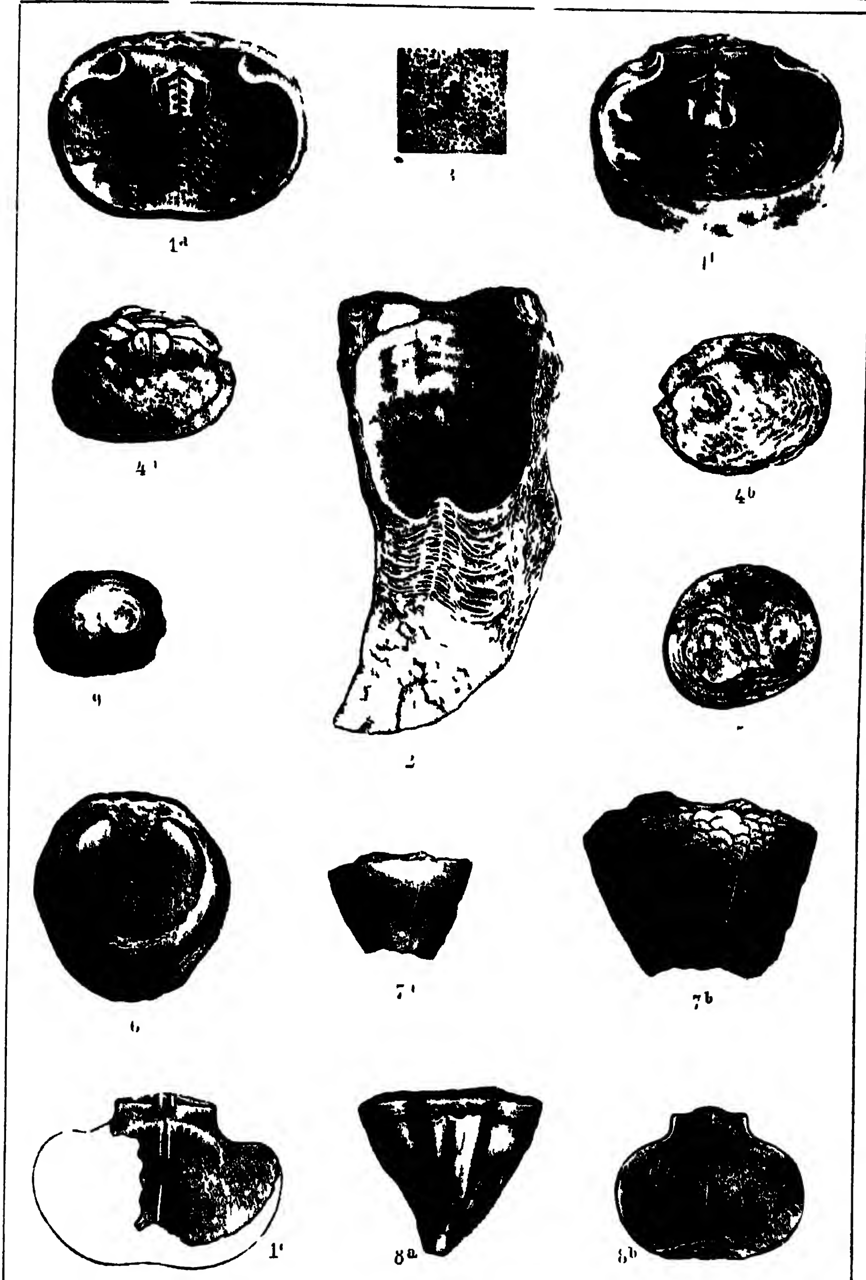
" 5. Artificial transverse section through a specimen from the Lower Productus-limestone of Amb. The two lateral vertical septa unite in the middle.

" 6. One of the partitions of the larger valve seen from below on a broken specimen from the Middle Productus-limestone of the Chittawán.

" 7. Fragmentary specimen, showing the cellular structure of the median shell-layer, the outer layers having been removed by weathering; from the Middle Productus-limestone near Khura.

" 8. Partial internal cast of a specimen from Musa Kheyl; *a*, view from the hinge-line; 8*b*, view from the smaller valve.

" 9. Small specimen from the lowest beds of the Middle Productus-limestone of Katta from below, showing the point by which it has been fastened to the bottom of the sea.



A Swoboda del & lith

Imp Th. Bannwarth Vienne

Waagen: Richthofenia. Pl. 2.

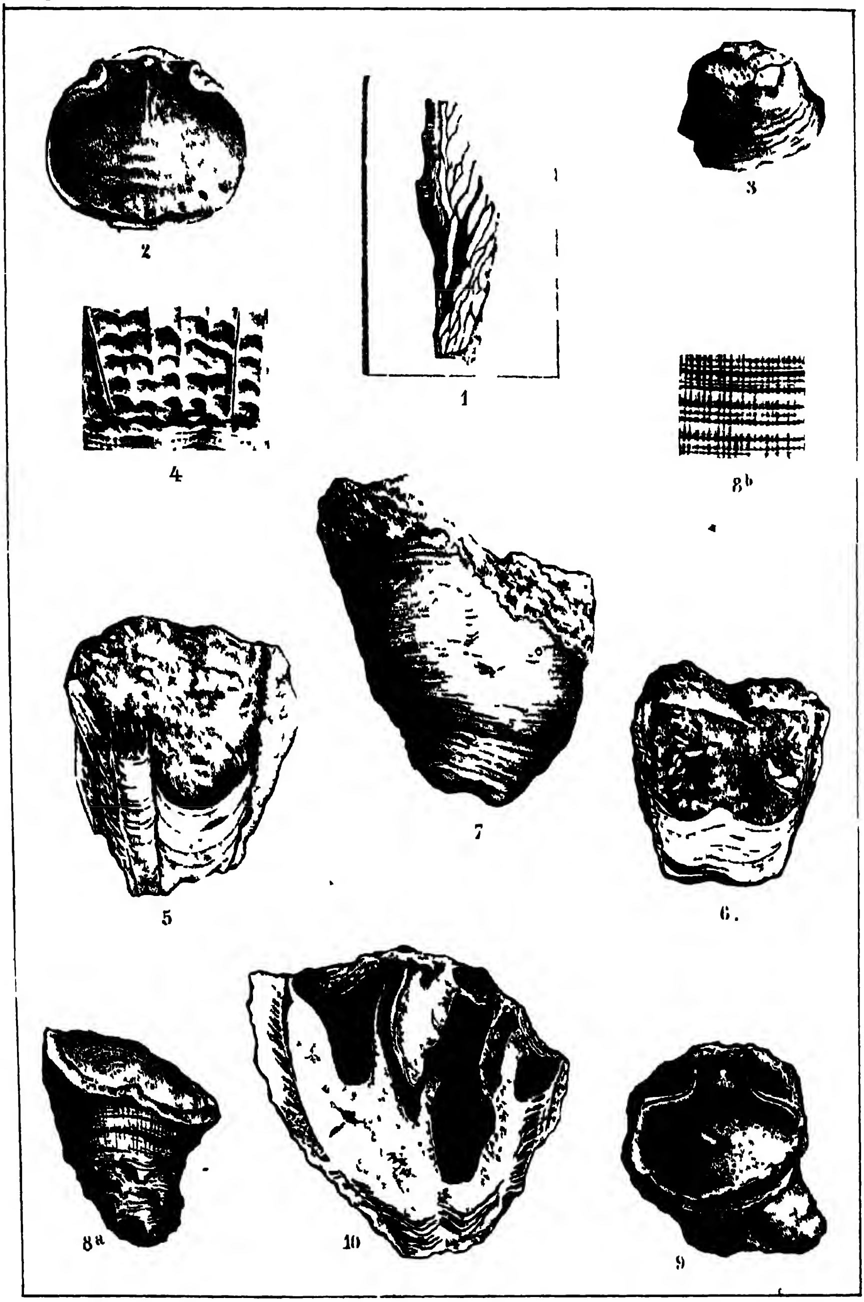


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PLATE II.

Figs. 1—9. RICHTHOFENIA LAWRENCIANA, Kon. sp.

Fig. 10. HIPPURITES, sp.

Fig. 1. Section through the shell of a specimen from the Lower Productus-limestone of Amb enlarged four times. To the right the outer, to the left the inner, side of the shell, at the lower extremity one of the shelly cones which traverse the shell substance; prisms slightly indicated.

„ 2. Internal cast of the smaller valve of a specimen from the Middle Productus-limestone of Musa Kheyl. The spines on the inside of the valve appear as deep grooves.

„ 3. Fragmentary specimen from the Middle Productus-limestone of the Chittawán, viewed from below, to show the irregularity of the partitions, the one figured being made up of five pieces.

„ 4. Fragment of the shell of a specimen from the Upper Productus-limestone (Cephalopoda bed) of Jabi, very obliquely weathered and enlarged about four times, to show the cells and the, in this case exceptionally numerous, shelly cones which are between them.

„ 5. Artificial section through a specimen from the Lower Productus-limestone of Amb. The section is vertical to the hinge-line, just missing the median vertical septum, but yet hitting at the upper end of the columella the secondary septa which are joined to the median one. Mineral matter partly intercalated between the partitions, as in all sections (Pl. I, fig. 2; and Pl. II, fig. 6).

„ 6. Artificial section through a specimen from the Lower Productus-limestone of Amb, the section being parallel to the hinge-line, missing the three vertical septa altogether.

„ 7. External view of a fragmentary but tolerably large specimen from the Middle Productus-limestone of the Chittawán.

„ 8. Specimen with exceptionally well preserved external surface of the larger valve, showing the longitudinal striation from the Lower Productus-limestone of Amb. 8*a*, lateral view, obliquely to the hinge-line; 8*b*, portion of the surface enlarged.

„ 9. Specimen from the Lower Productus-limestone of Amb; view from above to show the smaller valve and the fine granulations by which this as well as the bent over parts of the larger valve is covered.

„ 10. Section through *Hippurites* sp. from the Gosau formation of the Neue Welt near Vienna, figured for comparison with fig. 5. (Property of the K. K. Geologische Reichsanstalt in Vienna.)

On the Geology of South Travancore, *by* R. BRUCE FOOTE, F.G.S., *Deputy Superintendent, Geological Survey of India. (With a plate and a map.)*

My colleague, Dr. King, was from various causes obliged to leave the survey of South Travancore, from Trevandrum to Cape Comorin, very unfinished, and it devolved upon me to close up the gap left, so as to join the general survey of this State with the work I had done in Tinnevelly district. The small map which accompanies this paper shows the tract omitted in Dr. King's map, appended to his two papers relating to Travancore, published last year (1882)[1]. The notes I have to offer refer mainly to the tract lying between the coast and the high road leading from Trevandrum into Tinnevelly district through the Arambuli (Aramunny) pass.

The topographical features of South Travancore differ as greatly from those of the adjacent part of South Tinnevelly as do the climates of the two districts. The flat, sandy, and often barren plains of Tinnevelly are replaced by a very broken, rugged country, out of which rise numerous hills and rocky ridges, the whole thickly covered by rich vegetation. With the exception of a couple of score of square miles immediately to the north of Cape Comorin, the whole of South Travancore lies westward of the watershed along the Southern Ghâts, which mountain range causes both the moist climate of Travancore and the dry climate of Tinnevelly, by intercepting from the latter practically the whole supply of rain brought by the south-west monsoon, and causing it to fall on their western slopes. A small tract around Cape Comorin, in the extreme south-east corner of Travancore, has a climate and shows a flora corresponding to the dry one of Tinnevelly. But within a very little distance to the westward a great change begins, and the climate and flora both assume an intermediate character, which may be traced over a tract extending from the Cape like a narrow wedge (in plan), having a base of some 20 to 25 miles along the coast, with its northern angle in the Arambuli pass. Close to the main mass of the mountains the change of climate and flora is far more abrupt, and really takes place within a distance of a very few miles, *e. g.*, near Mahendragiri, the most southerly high mass of the Ghâts (5,455 feet), where the change takes place in about 2 miles.

The country owes its shape to the erosion of the old crystalline rocks which has taken place on the most gigantic scale, proofs of which will be adduced further on. Dr. King, in his general sketch of the Travancore country, points out (p. 88) the *quasi-terraced* arrangement the country shows, descending by steps, as it were, from the mountains to the coast. This terrace arrangement is much less well marked, however, in South Travancore than further to the north-west. The several terrace steps are marked by the existence of some ridges near the coast higher than the general surface of the country further inland. The most conspicuous of these is a considerable mountain mass lying north and north-east of the old fort of Udagiri (Oodagerry).

[1] See *a.*—General sketch of the geology of Travancore State. By W. King, D. Sc., Deputy Superintendent (Madras), Geological Survey of India.

b.—The Warkilli beds and reported associated deposits at Quilon, in Travancore. By W. King, D. Sc., &c., (with a map). Records, Geological Survey of India, Vol. XV, pp. 87—102.

The real southern termination of the Southern Ghats occurs in north latitude 8° 15′, where the high mountains sink down into the Arambuli pass. Southward of the pass rises the perfectly detached Kathadi Malai, a fine rocky mass between 2,000 and 3,000 feet high, which sends off a rocky spur extending southwards with two breaks, for a distance of 7 or 8 miles, and terminating in the bold Murtawa hill, 4 miles north-west of Cape Comorin. The Cape itself consists of low gneiss rocks, backed up by a palm-grown sand-hill, about 100 feet high. A pair of very small rocky islands rise out of the sea a few hundred yards east of the Cape, but they are not shown in Atlas-sheet 63, any more than are various other rocks occurring off the coast opposite Muttum[1], Kolachel (Colachull), and Mel Madelatorai (Maila Muddalathoray), which are the culminating points of reefs formed by ridges of gneiss running parallel with the coast. At Kolachel, which is the seaport of South Travancore, the lie of the rocks is such that it would be easy to connect them by short rubble breakwaters, and thus to form a very useful little harbour in which coasting craft could easily lie up during the south-west monsoon.

It will be seen by the map that a broken band of younger rocks occupies a very great part of the tract lying between the coast and the Trevandrum-Tinnevelly high road above referred to. There can be no doubt that these younger rocks not very long since, geologically speaking, formed an unbroken belt which extended considerably further inland than at present. The denudation they have undergone has been very great, both vertically and laterally, and the remnants of them left are in various places of such trifling thickness that all traces of their former existence will soon be effaced. They show most in the western part of the area under description, where they form small plateaux, which are well marked, except to the north, on which side they lap on to the rising surface of the gneiss and thin out, or are lost sight of, in the Kabuk or pseudo-laterite formation, a rock resulting from the decomposition of ferruginous beds of gneiss. The surface of the plateaux, where not greatly eroded, is gently undulating and often supports a very dense and varied vegetation. The less compact portions of plateau surfaces are often cut into small, but very deep, rain gullies which render many places impassable for any but foot passengers.

The most striking feature in the flora of South Travancore is the immense forest of fan palms (*Borassus flabelliformis*), which covers great part of the country. The fan palms, or palmyras, attain here to much greater height than they generally do elsewhere. Trees measuring from 90 to 100 feet in height are not uncommon in places, and, with their stems greatly covered by white, or silvery, grey lichens they present a much finer appearance than the comparatively stunted specimens one is accustomed to see in the Carnátic, or on the Mysore and Deccan plateaux. Whether these Travancore trees owe any part of their greatly superior height to superior age, as compared with the palms in the great palmyra forest in South Tinnevelly, I could not make out; but the white colour of their stems, added

[1] These rocks, and especially one called the Crocodile rocks, were sources of great danger to the coasting ships, but that has been removed by the erection on the Muttum headland of a light-house just completed.

to their great height, certainly gives them a much more hoary and venerable appearance.

To the westward of the Cooletorary river the palmyra trees are less striking features in the landscape than to the eastward. Cashew nut trees (*Anacardium occidentale*) are also very largely cultivated, and attain to greater size than anywhere in the Carnatic. Jack (*Artocarpus integrifolium*) and Alexandrine laurel (*Calophyllum inophyllum*) are also very common trees in South Travancore. Coco and Areca palms are commonly planted in the sides of the numerous little narrow valleys which score the face of the country, each with a rice flat in the bottom.

The backwaters at the mouths of the several rivers, and the canals connecting them, are often thickly fringed with screw pine (*Pandanus odoratissimus*); and a large fern, *Acrostichum aureum* (Linn.), is generally very conspicuous among the smaller bushes standing in the shallow water. One of the finest displays of tropical vegetation I am acquainted with in South India may be seen to great advantage by going in a canoe up the Cooletorary river for 3 or 4 miles from its mouth at Tengapatanam (Taingupatnum). The varying effects of dense lofty palm groves, interspersed with large forest trees and fringed with *pandanus*, &c., along the water's edge, and backed by the beautiful blue outlines of Agastyamalai and other peaks of the Southern Ghâts cannot fail to delight the eye capable of appreciating a series of perfect landscapes. Near the upper end of the navigable reach the beauty of the scene is increased by the presence of great granite gneiss rocks towering up here and there in the forest on either side of the river. Two other views, specially worth seeing, should be mentioned when describing the topography of this picturesque country. The first of these is due north from the bar at Mannagudi, 4 miles west of Cape Comorin. The eye here ranges across a large sheet of fresh water, set among palms, making a glorious foreground to the mountains which rise to the north, Mahendragiri and the great mass of the Mutukulivayal plateau standing out boldly. The second view to which I wish to draw attention is to be seen from the white rock spit about 1½ mile north-eastward of Cape Comorin. From here the south end of the ghats is seen across a lovely bay, with broken rocks and surf in the immediate foreground. The bright blue waters of the bay set off the fine tints of the nearer mountains to perfection, while the noble outlines of Mahendragiri and its companion peaks form a back ground of wonderful beauty. The view on a good day far surpasses the best of the views across Bombay harbour, about which so much has been written. From the Cape itself the mountains are not seen at all, being shut out by sand-hills, topped by a forest of palmyras.

In the foreground of the view from white rock spit the most characteristic trees are umbrella trees (*Acacia planifrons*), the most typical trees of the arid Tinnevelly plains, which are seen across the bay stretching away far to the north-east. A few miles to the west of the Cape these trees become very rare or have disappeared entirely.

Very conspicuous features in the landscape of South Travancore, as seen from the deck of a vessel passing off the coast, are several patches of intensely red rock or sand standing close to the beach, but perched up at a considerable height above the water's edge. These are *teris*, or red blown sands, capping cliffs of red sandstone, both of which formations will be referred to at length further on.

The various geological formations to be found in South Travancore may, for convenience of reference, be arranged in a tabular scheme as below :—

RECENT	...	Blown sands: the red (teris), and the white (coast dunes). Soils; kankar deposits; ferruginous breccias (lateritic). Marine and estuarine beds.
TERTIARY ?		Sands and clays (Warkilli beds, ? Cuddalore sandstone.)
AZOIC	...	Gneissic series.

The Gneissic Series.

In no part of the peninsula, perhaps, is there a greater and finer display of the ancient crystalline rocks than in the Southern Ghâts in their southern half, and in the great spurs and outlying masses on their western or southern side. The disposition of the beds in South Travancore, when laid down on the map, shows the existence of a great synclinal curve, probably an ellipse, the major axis of which passes through, or very near to, the great mass of Mahendragiri; while the north-western focus (if the ellipse be a complete one) will be found somewhere to the north-eastward of Allepy. I had inferred the existence of this great synclinal ellipse from studying the course of the great gneiss beds on the eastern foot and flanks of the mountains southward of Courtallum, and Mr. King's examination of the gneiss country across the Shenkotta pass and southward to Travancore independently demonstrated the existence of the central part of this huge synclinal fold. The topographical shape of the ground, as shown in Atlas-sheet 63, points strongly to the fold being a true ellipse, the extreme north-western extremity of which is probably hidden under the alluvial bed north of Allepy, while the extreme south-eastern apex lies most likely in the sea to the E-N-E of Cape Comorin. The curve of the coast from Cape Comorin north-westward to close up to Trevandrum coincides with the south side of the great synclinal, and the different ridges inland also coincide absolutely with the strike of the harder beds of the series. Several southerly dips were noted in the rocks on the coast westward of Kolachel, which looks as if the axis of an anticlinal had there been exposed, but they may possibly only represent trifling Vandyke-shaped bends or crumples, in the side of the great synclinal. To the north of the area under consideration the rocks roll over northward into a great anticlinal fold.

The true bedding of the gneiss on a large scale is extremely well displayed in the great outlying mass known as the Udagiri or "Murroovattoor" mountain. Both strike and dip are admirably seen from the travellers' bungalow at Nagar Kovil. One of the finest examples of a sheer naked wall of rock to be seen in South India is shown in the tremendous cliff forming the S. E. front of the Tiruvuna Malai, the great eastern spur of Mahendragiri. This bare precipice must be fully 2,000 feet or more in height, many hundred feet in the central part being absolutely vertical, or even overhanging a little. As might be expected, this great mass has attracted much notice; it forms the Cape Comorin of some sailors, and of Daniel's famous view of that cape, though in reality some 16 miles from the nearest point on the coast and 28 miles from the cape itself. Even the Hindu mind, generally so stolid about the beauties of landscape scenery, have connected this noble mountain with the name of Hanuman, the famous monkey god, who is said to have planted one foot on each of the two Peaks and to have jumped across the Gulf of Manar and alighted on Adam's Peak, a standing jump of 220 miles odd being a trifle for the long-tailed divinity.

Another grand precipice occurs on the south-east face of the Taduga Malai, at the western end of the Arambuli pass. The cliff-faces in both these splendid scarps coincide with great planes of jointing.

The predominant character of the gneiss rocks in this quarter is that of a well-bedded massive, quartzo-felspathic granite gneiss, with a very variable quantity of (generally black) mica and very numerous small red or pinkish garnets. This is the characteristic rock at Cape Comorin, and very generally throughout South Travancore, and Tinnevelly district as well.

Scattered grains of magnetic iron are commonly met with in the weathered rocks. No beds of magnetic iron were noted by me, but some may very likely occur, and would go far to account for the enormous quantities of black magnetite sand cast up on the beach at frequent intervals along the coast and of which the source is at present unknown, unless it has been brought by the south-westerly current prevailing during the south-west monsoon. The source of the garnets which form the crimson sand, which is of nearly equally common occurrence, is not far to seek, for it is hardly possible to find a bed of rock which does not abound in garnets. The so-called "fossil rice" found at the extreme point of land close to the cape is merely a local variation of the quartz grains set free by degradation of the rock. They assume the "rice" shape after undergoing partial trituration in the heavy surf which beats incessantly on the southern coast.

The sub-aërial decomposition of the felspatho-ferruginous varieties of the gneiss produces in the presence of much iron a pseudo-laterite rock very largely developed over the gneissic area described by Dr. King in his Sketch of the Geology of Travancore under the name of lateritised gneiss, a rock which is popularly called laterite in Travancore and kabuk in Ceylon. In numberless places this peculiar decomposition of the gneiss, which is pre-eminently characteristic of very moist climates, has altered the rock *in situ* to variable, but often considerable, depths, and the original quartz laminæ of the gneiss remain in their pristine position, and often to all appearance unaltered, enclosed in a ferruginous argillaceous mass formed by the alteration of the original felspar, mica, garnets, and magnetic iron. The colour of this generally soft mass varies exceedingly, from pale whitish pink to purple, red and many shades of reddish brown and brown according to the percentage of iron and the degree of oxidation the iron has undergone. The bright colours are seen in the freshly exposed kabuk or pseudo-laterite, but the mass becomes darker and mostly much harder as the hæmatite is converted into limonite by hydration, and more ferruginous matter is deposited, as very frequently happens, by infiltration. The pseudo-laterite formed by accumulation of decomposing argillo-ferruginous materials derived from distant points is to be distinguished generally by the absence of the quartz laminæ as such. The quartz grains are generally much smaller, and are scattered generally through the whole mass of new formed rock. One excellent example of the pseudo-laterite formed by the decomposition *in situ* is to be seen in a steep bank in the zoological gardens in Trevandrum, close to the Tapirs' den. Equally good examples are very common in many of the cuttings along the high road east of Trevandrum.

The washed-down form of pseudo-laterite often forms a rock intermediate in character between a true sub-aërial deposit and a true sedimentary one, and consequently by no means easy to classify properly. In fact, in a country subject to such a tremendous rainfall, the sub-aërial rocks must, here and there, graduate into sedimentary ones through a form which may be called "pluvio-detrital." Such pluvio-detrital forms occur very largely in South Travançore, but it is impossible in most cases to separate them from the true sedimentary formations they are in contact with.

The Warkilli or Cuddalore Sandstone Series.

The Cuddalore sandstone series, first distinguished on stratigraphical grounds as a separate geological group by Mr. H. F. Blanford, were by him supposed to be very probably of tertiary age. In the absence of sufficient palæontological evidence it was impossible to assign any more approximate position to these rocks, the silicified exogenous tree stems found at Tiruva-Karai, near Pondicherry, not being deemed of sufficient importance.

Other similar sandstone formations subsequently examined near Madras, in Rajahmundry district and on the Travancore coast near Quilon could, in the absence of all fossils, be assigned by myself and Dr. King only in a provisional way to the age of the Cuddalore rocks. Lithologically and petrologically these several sets of sandstones and associated clays, &c., show great resemblance, and their relative positions on or near the existing coast lines further justified their being provisionally associated, though separated by such great distances.

A very careful examination of the beds near Quilon by Dr. King, who had the advantage of seeing the fresh cutting made through plateaux of these rocks in connection with the new tunnel at Warkilli has unfortunately thrown no positive light on their true geological position. The vegetable remains associated with the lignite beds at base of the series proved insufficient to allow of determination of their own character, and consequently most unsuitable to assist in settling the homotaxy of the strata they occurred in. The sedimentary beds forming the belt of small plateaux fringing the coast of South Travancore must, on petrological grounds, be unhesitatingly regarded as extensions of the Quilon beds, or *Warkilli beds* of Dr. King. None of these formations which I traced from Villenjam, 9 miles south-east of Trevandrum, down to Cape Comorin, afforded the faintest trace of an organic body: thus, no light was thrown on the question of the geological age or homotaxy, but somewhat similar sandstones and grits are found on the Tinnevelly side of the extreme south end of the Gháts range, and in a coarse gritty sandstone, much resembling some of the beds in Travancore, a bed of clay is intercalated, in which occur numerous specimens of *Arca rugosa* and a *Cytherea* of a living species. The locality where these fossils of recent species were found occurs on the right bank of the Nambi-Ar, about 2 miles above its mouth and a few hundred yards from the bank of the main stream. All the sub-fossil shells I found here are of living species; hence the deposits enclosing them cannot be regarded as tertiary; and if the agreement of these Nambi-Ar beds with the Warkilli and South Travancore beds on the one hand, and the Cuddalore, Madras, and Rajahmundry beds, be assumed, as they must be on petrological grounds, the Cuddalore sandstones and their equivalents elsewhere must be accepted as of post-tertiary age. As far as it goes, the evidence is clear and distinct; but more evidence is required as to the age of some of the intermediate connecting beds, such as those south and east of Kudan-Kulam.

The typical section of the Warkilli rocks near Quilon, given by Dr. King, shows the following series:—

	Feet.
Laterite	30 to 40
Sands and sandy clays or lithomarge	58
Alum clays	25
Lignite beds	7 to 15
Sands	
TOTAL ...	120 to 138

with which we may compare the series seen in the fine section formed by the beautiful cliffs in Karruchel bay, 11 miles south-east of Trevandrum.

The section here exposed shows the following series of formations:—

	Feet.
4. Soil—dark red, sandy loam, lateritic at base	8 to 10
3. Sandstone—hard, gritty, purplish or blackish	?
2. Sandstone—gritty, rather soft, false bedded, often clayey in parts (lithomargic), variegated; in colour red, reddish-brown, purplish-white-yellow	40 to 50
1. Sandstone—gritty, rather soft, false-bedded, red, purple, pink, white, variegated; shows many white clay galls producing a conglomeratic appearance in section	40
Base not seen, hidden by sandy beach.	

The total thickness of these beds I estimated at about 100 feet; the upper part is obscure, from pluvial action washing down the red soil over the dark grits. The middle and lower parts of the section are extremely distinct, and the colouring of the beds very vivid and beautiful; but the beds are by no means sharply defined.

The beds dip north-easterly (inland), and from the slope of the ground on the top of the cliff the angle of dip may be inferred to be from 25° to 30°. Further inland, near Pinnacolum, the dark gritty sandstones lie horizontally, at a considerably lower level than at the top of the Karruchel cliffs, but rise again eastward. The middle gritty series is exposed along the western side of the Karruchel lagoon, but is highly lateritised by weather action. Three miles, or so, to the north of the lagoon, purplish gritty beds show strongly and form a small well-marked plateau overlooking the valley in which lies the village of Cotukall. That the gritty beds are sometimes replaced by clays is shown by the materials turned out of two deep wells sunk into this plateau at two points several miles apart; one of these wells lies rather more than half a mile to the northward of Mullur (Mooltoor of sheet 63). Here the section, which is from 80 to 100 feet deep, passes through mottled gritty sandstone and into blue and white mottled clay. The other section revealing clays below the gritty beds is in a well sunk close to the new road from Valrampur (Vaulrampoor) to Puar (Powar), and some distance south of the place shown in the map as Vunpoyal[1]. The clay here is of a similar white and blue mottled colour.

A section in the low cliff forming the small bay immediately east of Villenjam shows a mottled vermiculated clayey rock showing mostly no bedding at all. Traces of bedding are, however, revealed as the cliff is followed southward by the appearance of thin bands of grit near the base of the section which rests on the underlying quartzo-felspathic garnetiferous gneiss. This mottled clayey rock I believe to represent the bluish-white-mottled clay turned out of the lower parts of the well section near Mullur before referred to. It is locally considerably discoloured and stained by the percolation of water through the overlying pseudo-lateritic, dark-red sand. As will be seen by any one who follows the coast line these Warkilli sandstones rest upon a very rugged and broken gneiss surface. Many great tors and knolls of granite gneiss protrude through the sandstone plateaux or tower over them from adjacent higher ridges, which have been completely denuded of the younger rocks.

The greater part of the surface of the tract occupied by these Warkilli beds west of the Neyar is thickly covered by sandy loam, generally of dark red colour, which conceals the sub-rock very effectually, excepting where the loam is deeply eroded. A well-marked patch of purplish grit forms a knoll, about a mile south-west of Valrampur. Traces of the former, more easterly, extension of these beds are to be seen at intervals along and to the north of the Trevandrum-Tinnevelly road between Valrampur and Neyatum Karai.

In the tract lying east of the Neyap few sections exhibiting the grits, &c., were met with, and all were small and unsatisfactory. The surface of the country is either largely covered with the deep red soil, or else the extremely broken surface of the gritty beds is extensively lateritised. The appearance of the country when seen from elevated points is, however, characteristically very different from the gneiss and kabuk tract lying to the northward. This may be well seen from Colatoor trigonometrical station hill, as also from the high ground close to Cauracode, but yet more strikingly from the Kodalam Pothia, a hill 2 miles west-north-west of Paurashalay. Sections in which the true character of the rock is to be seen occur on the high ground close to the junction of the new roads leading from Puar (Powaur) and Martanda Putentorai respectively to Paurashalay, also to the southward near Shoolaul (of map), where a large rain gully cuts deeply into the grits and underlying clayey beds; also along the ridge of high ground north and

[1] I failed utterly in identifying this and many other of the village names given on the map (sheet 63). It was very difficult to localise the positions of many phenomena I wished to record, even if landmarks existed on which to take bearings, owing to the extreme inadequacy of the map. The fact that the villages and hamlets generally straggle far and widely over the face of the country, instead of coinciding with any points indicated on the map, does not at all assist one in fixing one's whereabouts in the absence of landmarks.

north-east of the Yeldaseput of the map. Traces of the former eastward extension of the grits were noted on the eastern flank of the Kodalam Pothai, and on high ground half a mile or so to the northward of the cutcherry at Paurashalay. The beds composing this patch of Warkilli rocks have undergone greater superficial denudation than those in the Karruchel patch to the north-west.

In the small patch lying east of the Kuletorai (Cooletoray) river some instructive sections of hard dark grits and underlying clayey grits of the usual reddish, bluish, and white mottled colour are to be seen south of Killiur (Killioor). Some of the sections show regular miniature 'cañons' 15′ to 20′ deep, with vertical sides and numerous well formed pot-holes. Hard purplish grits show on the surface between Killioon and Pudukaddi (Poodoocudday) and soft mottled grits in a well section close east of the little D. P. W. bungalow at Tengapatnam, (Taingaputnum). At the southernmost point of this Killiur patch the grits become coarsely conglomeratic over a small area. A little to the north of this the grits, when resting on the basset edge of a bed of granular quartz rock, present the characters of a perfect arkose, made up of the angular gneiss debris. In places this arkose might be most easily mistaken for a granitic rock.

A distinctly conglomeratic character is shown by the grit beds close to Madalam (Muddaulum). This Madalam patch of Warkilli sandstones is on its southern side deeply cut into by a gully which exposes regular cliffs with from 35 to 40 feet of coarse or conglomeratic mottled grits, capped by thick red soil. The grits contain many large clay galls and lumps of blue or mottled colour.

In the Kolachel (Collachull) patch the grits are extremely well exposed in deep cuttings (miniature cañons) made by the stream rising just west of Neyur. They are of the usual mottled description. Where seen at the eastern side of the patch near the Eranil (Yerraneel) cutcherry they are quite conglomeratic.

They are exposed also in a gully crossing the road which runs north from Kolachel to join the main road, and in a well-section on the high ground a mile north-eastward of the little town. The south-eastern part of the patch is entirely obscured by a great thickness of dark red soil. They peep out, however, below the red soil at the western end of the great tank 3 miles south of Eranil (Yerraneel).

A very thin bed of conglomeratic grit underlies the *teri*, or red sand-hill, capping the high ground north of the Muttum (Moottum) headland. Further east a few poor sections only of whitish or mottled grit prove the extension of the Warkilli beds in that direction, nor are they well seen again till close into Kotar, where they show in various wells and tanks, but are still better seen in a deep rain gully south of the travellers' bungalow at Nagar Koil, and in a broad cutting immediately to the east of the bungalow. The variegated gritty sandstones here seen are very characteristic, and strongly resemble some of the typical varieties in South Arcot and Madras districts.

To the south of Kotar the grits are to be seen in streambeds opening to the Purrakay tank, and in a series of deep rain gullies on the eastern slope of a large red soil plateau to the south-west of Purrakay.

A small patch of gritty sandstones of similar character to the above occurs immediately north and north-west of Cape Comorin. As a rule, they are badly exposed, being much masked by the red-blown sand of a small teri. The most accessible section is a small one seen in the bottom of a good-sized bowrie, a little south of the junction of the roads coming from Trevandrum and Palamcotta. This section can only be-seen when the water in the bowrie is low. A considerable spread of similar greyish or slightly mottled grits is exposed about half a mile to the north-east of Cova Colum, and 1½ miles north-west of the Cape. Lying between the two exposures just mentioned, but separated from either by spreads of blown sand, is a different looking vermiculated mottled grit of much softer character. This is extensively exposed in the banks of a nullah and head-water gullies falling into the Agusteshwar. The colour of this soft grit ranges from red, through buff to whitish. The beds roll to the northward. This grit is full of vermicular cavities filled with white or reddish kankar (impure carbonate of lime). The grit seems to graduate upward into a thick red gritty soil full of small whitish red, impure (gritty) calcareous concretions. There is good reason, however, for thinking that this graduation is merely apparent, and that the red gritty soil is only the base of a red sand-hill, or teri, undergoing change by percolation of calciferous water. A hard brown grit is exposed for a few square yards just north of the junction of the two roads above referred to. This rock has, except in colours, considerable resemblance to the red-white grit just described, and both probably overlie the pale mottled grits near Covacolum.

The last patch of grits to be mentioned forms almost the extreme easterly angle of the Travancore territory, and lies to the eastward of the southernmost group of hills and along its base. Not many sections of the grit are here exposed owing to a thick red soil formation which laps round the base of the hills, and is only cut through here and there by a deep rain gully or a well. The grits here seen are like those exposed near the travellers' bungalow at Nagar Koil, but show much more bedding and are almost shaly in parts. The colour of the grit is white, pale drab or grey mottled with red and brown in various shades. They lie in depressions in the gneiss, and were either always of much less importance and thickness than the beds to the west, or else have been denuded to a far greater extent. They are best seen in gullies to the south-west and west of Russhun Kristnapur, 7 miles north of Cape Comorin, and in the beds of the small nullahs west and north-west of Comaravaram opposite the mouth of the Arambuli pass. None of these Warkilli grit beds occurring between Trevandrum and Cape Comorin have yielded any organic remains as far as my research has gone, and I fear none will be obtained by subsequent explorers. The alum shales occurring in Dr. King's Warkilli section have not been traced in South Travancore, and I had not the good fortune to come across any lignite. It is said to occur not unfrequently to the south of Kolachel, and to be turned up by the people when ploughing their fields. I have no reason to doubt this, for it is extremely probable that some of the clayey beds should contain lignite. From the configuration of the ground, too, the paddy flatalong the southern boundary of the Kolachel grit patch would coincide in position with some of the clayey beds near the base of the series which are lignitiferous at Warkilli; and why not at Kolachel?

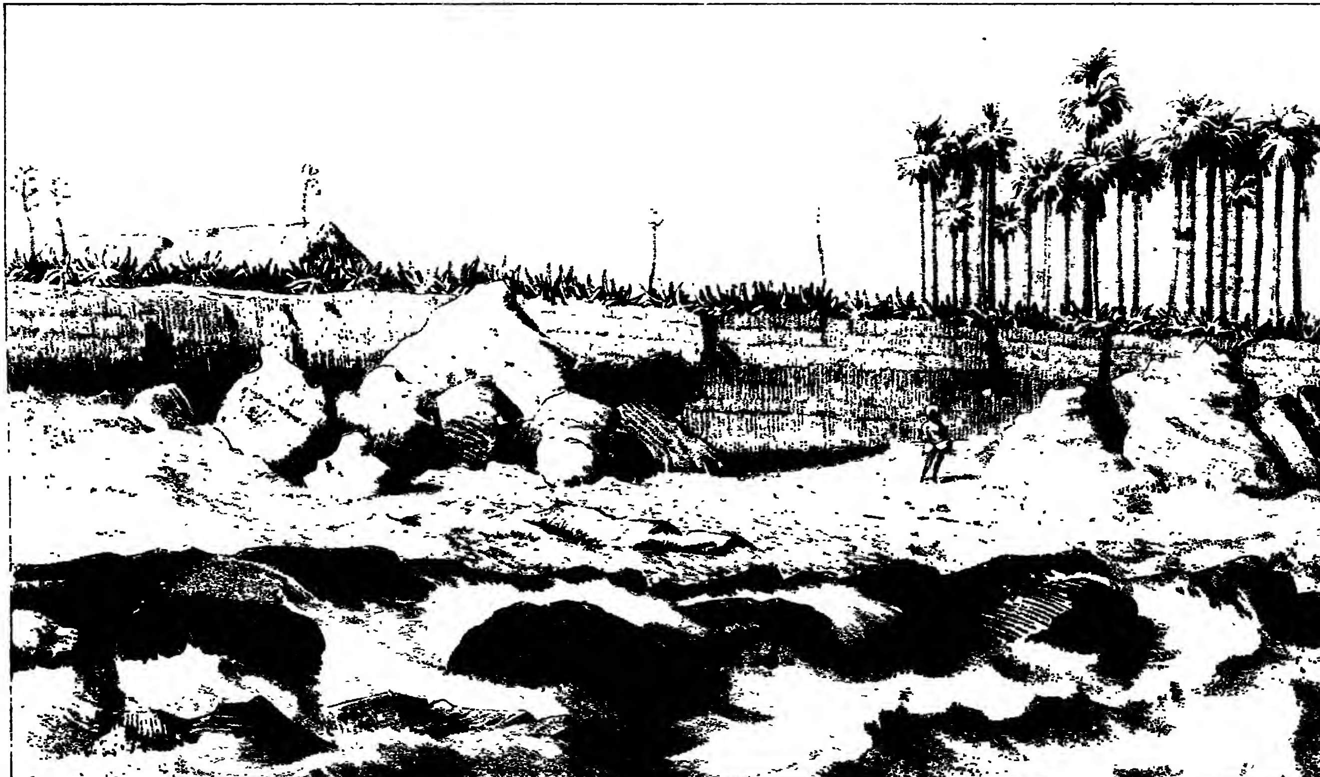
The recent discovery of lignite in the Cuddalore sandstones at Pondicherry adds greatly to the probability of the correctness of Dr. King's and my conclusion (arrived at by us separately and independently before we had an opportunity of comparing notes) that this gritty bed in Tinnevelly and Travancore should be regarded on the grounds of petrological resemblance and identity of geographical position as equivalents of the Cuddalore sandstones of the Coromandel coast.

The question of the age of these Cuddalore or Rajahmundry or Warkilli sandstones I propose to examine in the Memoir on the Geology of the Coastal region of Tinnevelly and Madura districts which I am now preparing.

The Marine Beds.

At Cape Comorin and two other places along the coast to the northward are formations of small extent but very considerable interest, which, by their mineral constitution and by the abundance of fossil marine shells they enclose, show themselves to be of marine origin, and thus prove that the coast line of the peninsula has undergone some little upheaval since they were deposited. These beds are to be seen close to the Cape at the base of a small cliff which occurs immediately south of the Residency bungalow, and only about 200 yards west of the Cape itself. The annexed plate is a truthful sketch of the little cliff, taken from a mass of gneiss rock projecting some little distance out to the south. The rocks seen in the surf, and immediately behind it on the beach, are all gneiss. The base of the small cliff is composed of friable gritty calcareous sandstone, full of comminuted shells. The base was not exposed at the time I examined this section, some heavy gale having piled up the beach sand against the foot of the cliff, and for this reason it was impossible to trace the probable connection of this sandstone with another exposed at a slightly lower level at a few yards distance to the west and just beyond the left-hand limit of the sketch. This lower bed is similar in mineral character, but very hard and tough, and offers great resistance to the surf, but has nevertheless been deeply honeycombed and in places quite undermined. The roof of the miniature caves thus formed have in some cases fallen in, but have been partly re-cemented by deposition of calcareous matter in the lines of fracture. To return to the cliff section, the basement sandstone is overlaid by a similar but slightly harder yellowish friable bed, which contains many unbroken shells (all of living species), in addition to a great quantity of comminuted ones. The base of the lower bed is hidden by sands, but from the proximity of the gneiss it cannot exceed 5 or 6 feet in thickness, while the overlying shelly bed measures about the same. It is overlaid in its turn by a massive bed, 6 to 10 feet thick locally, of a kind of travertine formed of altered blown sand, composed mainly of fully comminuted shells. This travertine contains immense numbers of shells and casts of *Helix vittata*, the commonest landshell in the south; it will be described specially further on. Owing to the soft character of the marine sandstones, the cliff has been much undermined by the tremendous surf which breaks on this coast in bad weather, and great masses of the hard travertine of the Helix bed have fallen on to the beach, as shown in the sketch, forming a partial breakwater against the inroads of the sea.

The shells contained in the upper sandstone bed were all found to be of living species, where sufficiently well preserved to admit of identification, the majority of the specimens are too ill preserved for specific identification. Four miles north-



CLIFF SECTION WEST OF CAPE COMORIN

north-east from "the Cape," as it is locally termed, stands the little stone-built fort of Watta Kotai (Wutta Kotha), which is built upon a small patch of calcareous sandstone, full of marine shells, exposed in the moat along the north face of the long curtain wall which joins Watta Kotai fort with the extensive series of fortifications known as "the Travancore lines." The marine limestone may be traced for nearly half a mile inland in the bottom of the moat. This marine bed is overlaid by a very thin bed of travertine limestone full of *Helix vittata;* it has been cut through in the formation of the moat. The thickness of the shelly marine bed is unknown, but the Helix bed is not seen to exceed 10″ or 1′ in thickness. As far as seen in the very small exposure, both formations lie nearly horizontally. Another small exposure of the marine bed occurs at the western end of a little backwater (not shown in the map) to the north of the port. The sandstone here contains many well preserved marine shells, all of living species; but further west, where the bed is exposed below theHelix bed in the moat the enclosed shells are all broken and comminuted. The surface of sandstone, as seen at the end of the little backwater, is raised but a very little distance above the sea level, probably not more than 4 or 5 feet at the outside. The rise of the ground along the moat is extremely small, and even at the furthest point from the sea at which the sandstones are exposed the elevation is probably not more than 10 or 12 feet at most, which would correspond with the top of the sandstones as seen in the little cliff at Cape Comorin.

About 2 miles north-east-by-north of Wattakotai fort a small patch of white shelly limestone occurs peeping out of the low belt of blown sand which fringes the coast at that spot. The village of Kanakapur which lies immediately to the north is the last within the Travancore boundary. The limestone only stands out a few inches above the surface of the surrounding sands, and no section could be found to show its thickness, but in point of elevation above the sea level it agrees perfectly with the Watta Kotai and Cape Comorin beds. The limestone which is fairly hard is quarried for economic purposes, and unless a good deal more of the bed than now meets the eye remains hidden under the sands, it will, before many years are over, have been removed by human agency.

The shell-remains occur as impressions and casts of great beauty and perfectness, but the shelly matter has disappeared entirely, being probably slightly more soluble than the enclosing limestone. The limestone contains a large number of specimens of *Helix vittata* which were evidently carried out to sea and there entombed in a shallow water formation. To any one who has noticed the enormous numbers of this Helix living in this neighbourhood, and in the southern districts generally, the large number of it occurring fossil in this marine bed will be a matter of no surprise.

The Blown Sands.

Two very marked varieties of Æolian rocks occur along or near the coast of South Travancore, as well as along that of Tinnevelly; they are the red sands, forming the well known *teris* of Tinnevelly, where they are developed on a far larger scale, and the white sands forming the coast dunes. In South Travancore, as far as my observation went, the red sand hills are no longer forming; all are undergoing the process of degradation by atmospheric agencies, at various rates of speed. The red sands have in many places ceased to yield to the influence of the winds and have arrived at a condition of fixity and compaction caused by the action of rain falling upon the loose sands percolating through them and during heavy showers flowing over their surfaces and washing the lighter clayey and smaller, though heavier, ferruginous particles down the slopes of the hills or into hollows on the surface, where, on drying, a fairly hard, often slightly glazed, surface of dark red loam has been formed. This loam is very fairly fertile and soon becomes covered with vegetation, which further tends to bind the mass together and render the surface secure from wind action. The loose sand, deprived of the clayey and finer ferruginous particles, would, unless unusually coarse in grain, be carried off by high winds elsewhere or remain in barren patches on the surface. I believe this process has gone on extensively over many parts of South Travancore, and explains the existence, on the surface of the country and resting indiscriminately on the gneiss and the younger rocks as the Warkilli sandstone, of the great thick sheets of pure red loam which have not been brought there by ordinary aqueous deposition nor formed *in situ* by the decomposition of the underlying rocks. The percolation of the rain-water through the mass has in many places given rise to the formation of concretionary ferruginous masses, which are often strongly lateritoid in their aspect. The quantity of clayey matter and of iron ore in the form of magnetic iron is very great in the sand of many of the teris. The greater quantity of the water falling on the teris, as on other blown sand surfaces, escapes by percolation, and it is a common phenomenon to find springs issuing around the foot of the sand mass during the rainy season and becoming dry in the hot or rainless season.

The teris in South Travancore which still retain their character as accumulations of moving red sands are four in number and all very small, the largest not measuring one square mile in area. They are all close to the coast and with one exception stand high and conspicuous to ships passing along at a fair distance. The largest and most conspicuous is that at Muttum which caps the high ground with the new light-house. The process of fixation has gone on here largely and the moving sands cover a much smaller space than does the fixed portion[1]. The same may be said of the teri resting on the south-eastern extremity of the Kolache (Colachul) sandstone plateau. To the north-west of Kolachel are two much smaller teris at the distances of 3 and 5½ miles respectively. In both of these also the area of the fixed sand far exceeds that of the loose. Especially is this the case in the more northerly teri near Mel Madalatorai (Maila Maddalaitoray). Here the fixed part has undergone tremendous erosion and is traversed by long and deep rain gullies, with vertical sides up to 20 or 25 feet high. Gullies on a yet larger scale are to be seen at the south-east corner of the Kolachel sandstone patch and at the eastern side of the Muttum patch. Very large but shallower gullies are to be seen at the south-east corner of the Nagarcoil patch, where there is a very large fixed teri.

[1] I have shown the extent of the unfixed or moving teris on the map; the fixed part I have treated as a soil and ignored accordingly.

The small *teri* immediately behind Cape Comorin is a very poor specimen of its kind, and, in fact, hardly deserves to rank as one owing to its pale colour and poverty in iron sand, but it will not do to class it as a coast dune, as it consists mainly of silicious sand, while the true dunes at the Cape consist mainly of calcareous sand composed of comminuted shells, corallines, nullipores, &c.

The sand of the typical teris is silicious or ferruginous (magnetic iron), the former being well rounded and coated with a film of red oxide of iron, which is removeable by boiling in nitric acid for a few seconds. Common as garnet sand is on the beaches of South Travancore, I never yet found a grain of it in the teri sand, where the latter was pure and had not been mixed with beach sand. Much difficulty exists as to the source whence the red sand was derived; but I will not attempt to discuss this question here, as I hope to treat it at much greater length than I could now, in a Memoir on the Geology of Tinnevelly and Madura districts which I have in preparation.

The coast dunes of South Travancore are, except close to the Cape, in no way remarkable. A large patch of small hillocks to the north-west of the mouth of the Kuletorai (Cooletoray) river was caused by the wind shifting a great mass of sand turned out when the new canal was dug and heaped up on the north bank of the canal.

Some tolerably high ridges occur 3 miles south-west of Kolachel. The sand here contains so much fine magnetic iron that it looks in parts of a dark grey colour, shading here and there almost into absolute black.

A considerable quantity of blown sand fringes the coast from the Muttum headland eastward to Cape Comorin, and between Pullum and Culladevella forms some considerable hills. At Covacolum the highly calcareous beach sand which forms many low hillocks has been solidified in several places into coarse shelly limestone. The Helix bed at Cape Comorin already referred to, when treating of the Marine-beds, is really an altered sand dune, the calcareous matter of which has, by percolation of acidulated water, been dissolved and re-deposited, on evaporation of the water, as a subaerial travertine. Countless thousands of *Helix vittata*, and a considerable number of shells of *Nanina tranquebarica*, the two commonest land shells in this part of India, have been inclosed and fossilised in the formation of this travertine, which is evidently in constant progress. The immense wealth of shellfish of all kinds, added to large quantities of corallines and nullipores, incessantly thrown up by the surf, furnishes an abundant supply of calcareous sand for the formation of this travertine, which forms a bank more than a mile long and rising some 80 feet or more above the sea at its highest point. Its inland extent cannot be ascertained, as it is covered by loose sands. It probably only extends 300 to 400 yards inland and abuts against a low ridge of gneiss.

Coral Reefs.

A few tiny fringing reefs are to be seen half to three-fourths of a mile west of the Cape, half in the surf at low tide, and wholly in it at high tide. They are now to be considered as dead reefs, abandoned by the polypes that built them. I examined most of them carefully, without finding any live coral, and was inclined to doubt the correctness of my inference, drawn from their tabular shape and many shallow basin-like cavities; but later on, when examining some identical fringing reefs off the Tinnevelly coast to the south of Kudung Kulam trigonometrical station (the south point of the Cape Comorin base-line), I found a considerable quantity of live coral lining the sides of the little basins, and equally large quantities of coral quite recently dead in adjoining basins.

A great deal of shell debris, sand and broken stone, is included in the mass of the reefs which in several places have formed around masses of rock standing in rather shallow water, and joined up many loose blocks of stone tossed on to them by the surf into tremendously coarse conglomerates. Some similar reefs, but of rather larger size, occur along the coast to north-east of Cape Comorin; in these the tabular mass extends from 10 to 40 and 50 feet in width, from the shore to the constantly surf-beaten outer edge. In one or two places parts of the reef had evidently been founded on sand, which had been washed away, leaving an unsupported surface of many square yards in extent, which the surf of the next high tide or first gale of wind would either break up or else again support with sand washed under it. These little reefs are worthy of much closer examination than I was able to bestow upon them

The coral fauna of the Cape Comorin sea is on the whole a remarkably poor one, as far as one may judge by what is to be found thrown up on the beach. Dredging might reveal much more, but unfortunately no boats are to be found there, only Kattumarams (Catamarans), which would not be the most convenient form of craft from which to carry on scientific observations. The sea here is, however, so very rich in animal life in many forms, that it would assuredly afford a rich reward to any one having a suitable vessel at command. I obtained in a very short time a far larger number of species of shells here than at any other place on the Indian coast.

Soils.

The prevalent soils are red ones, varying in the quantity of their ferruginous element. The red soils seen inland near the main trunk road are chiefly formed of gneissic debris by subaerial decomposition. The origin of the deep red sandy or clayey loams has already been discussed (*ante*, page 32). They occupy no inconsiderable area. True alluvial soils occur very rarely, if at all, now-a-days; those which fill the bottoms of the many valleys and creeks in which paddy is cultivated being greatly altered from their original condition by centuries of cultivation, and the addition of various mineral, vegetable, and animal manures. Estuarine beds full of subfossil shells, *Cytherea*, *Pottamides*, *Melania*, &c., of living species are exposed in the salt pans at the mouth of the Kolachel nullah.

The alluvium in the valley of the Paleyar, which flows south from the west flank of Mahendragiri past Nagurkoil, is, where pure, a coarse gritty silt.

Economic Geology.

Valuable minerals and metals are conspicuous by their absence in the part of South Travancore I had the pleasure of exploring. I came across no sign of any mineral industry, except the preparation of sea-salt in the pans near Kolachel, and traces of an old iron smelling industry carried on formerly at foot of the now bare and rocky hills east and north-east of Myladdy and some 7 miles north-west-by-north of Cape Comorin. Judging from the large quantity of iron slag here remaining, the smelting industry must have been an important one for native workmen. I could get no information about it on the spot. I met with no existing iron smelting industry in the villages I traversed, probably because of the absence of rich supplies of iron ores. The supply of beautiful building stone is practically unlimited, but not much use seems to have been made of it. Travancore architects seeming to prefer the use of wood, the chief large stone buildings are the extensive fortifications erected to bar the way into the country from the eastward, and known as the Travancore lines. They are mostly built of gneiss, Wattakotai port already referred to being a very fine example of excellent well-cut masonry. At the extreme south end of the lines, where they abut on the sea near Cape Comorin, blocks of the marine sandstone have been employed in the walls to some extent, but have been much affected by weathering. The old fort at Udagiri (Oodagerry) is another extensive stone building.

Of the temples, which are usually fine specimens of stone work in South India, I have nothing to say. Non-Hindus may not approach them for fear of rousing the fury of the ultra-bigoted Brahmans, who unfortunately retain far too much power in Travancore, and exercise it to the detriment of the country generally.

Some of the hard sandstones of the Warkilli series have been used for building to a limited extent, and I noticed not far from Puar a good example, perfectly new, of a stone cattle-trough cut out of homogeneous pale, purple and white, hard lithomarge of very jaspideous appearance. I did not see a similar rock *in situ*, but it evidently came from some bed belonging to the Warkilli series.

Some notes on the Geology of Chamba *by* COLONEL C. A. McMAHON, F.G.S.

I propose, in the present paper, to give the results of some tours in the mountains adjoining Chamba, in continuation of my papers "on the geology of Dalhousie," and "on the section from Dalhousie to Pángi"; and I pre-suppose, on the part of the reader, a knowledge of the facts recorded in those papers.

In the first instance, I shall ask the reader to accompany me from Basaoli, over the Bánjal (Banjil) and Chattar Dhár passes, to Bhadarwár (Badrawar).

Leaving Basaoli, the Siwaliks continue with a steady N.-E. 5° E. dip all the way to Bhond (Pood). About half-way to the latter village, the coarse conglomerates of this series give way to red clays and massive sandstones, which in their turn are succeeded, near Bhond, by a fine-grained conglomerate, corresponding to the topmost Siwalik beds of the Danera-Dalhousie section.

At Bhond, the Siwaliks dip under indurated red clays and fine-grained sandstones of dark-grey colour. Both the clays and the sandstones are full of fine specks of a silvery mica. These rocks, I presume, represent the Dagshai and Kasauli groups of the Sirmur series. They dip N. 11° E., and extend as far as Seloo.

These beds are followed by a massive quartzite of whitish colour, dipping east and then by the slates and limestones of the carbo-triassic series, which have also an easterly dip. The limestones are the ribbed variety previously described, and they continue to the top of the Bánjal pass, the elevation of which is, according to my aneroid barometer, 6,325 feet above the sea. At the top of the pass the rocks dip S.-W. 11° S., but the dip is high and nearly vertical. The carboniferous slates become very black as the gneiss is neared.

About 2 miles below the top of the pass, on the northern side, the first outcrop of gneiss appears. The rock, as seen in this section, is a thoroughly crystalline gneiss, but it is never granitoid. Its dip is nearly perpendicular. The gneiss continues down to the Sewa river,—the river that flows from the Chattar Dhár into the Ravi,—and as the stream is approached the dip becomes more moderate.

On the descent to the Sewa there is a bed or dyke of fissile trap, about 20 feet wide, in the gneiss. It appears to be a decomposed diabase. It is of greenish-grey colour and its specific gravity is 2·95. Under the blowpipe it fuses readily to a black magnetic bead. The microscope reveals pieces of still unaltered augite here and there. Felspar may be traced in it, but it is greatly altered. A banded, or pseudo-foliated appearance, observable in this rock, is due probably to the infiltration of water along lines of cleavage due to traction or pressure. Along these lines minute granules of quartz—some of them of elongated form—are visible. This mineral is doubtless a secondary product. The quartz does not contain any fluid cavities which are very abundant in the quartz of the gneiss.

At the point where the road strikes the Sewa, the gneiss is succeeded by blue, micaceous slate, and as Bani is neared, the dip of the strata reverts to N. 11° W. The schistose rocks are of a type commonly seen in the neighbourhood of Dalhousie (as, for instance, on the road to Chuári), crumbling to a soft bluish-white powder, suggestive of french-chalk.

The outer band of gneiss is, in this section, some thousands of feet thick.

I observed no outcrop of the trappean zone in this section; it has apparently either thinned out, or has been cut off by a fault.

Schistose rocks, dipping N.-E. 15° N., all of which could be matched in the Dalhousie area, continue from Bani to Loong, where the "central gneiss" crops out on the right bank of the Sewa. It runs thence in a nearly straight line, following the direction of the river and keeping on the right bank through Chunchli (Chounchli), and crosses the Sewa some distance above the last-named village.

At first the slates, in contact with the "central gneiss," dipped E. 11° N. *away* from the granitic rock, but afterwards they became perpendicular.

The granitoid gneiss here is a porphyritic and perfectly granitic rock, much traversed by joints, but I could not make out any bedding. At one place I noticed that it had intruded between the bedding of the slates. It continues for some miles, when the slates re-appear, dipping N.-E. 11° E. *away* from the granite. The road, from this point, runs, almost along the boundary of the granite and slates, up to the top of the pass (elevation 9,650′). The granite is never far from the road, on the right bank of the stream; whilst the slates are seen on the left bank all the way up.

The granitoid gneiss continues to be seen on the left of the road for about

2½ miles down the north side of the pass. From this point the slates continue down to Bhadarwár. The dip remains unchanged.

The Kund Kaplás (Koond Kaplas), in many respects, seems to be an analogue of the Chor mountain of the Simla area. It is 14,241 feet high, the elevation of the Chor being 11,982 feet; and like the Chor it abuts on the plains and appears to be formed of "central gneiss." It will be seen from the observations made on this tour, that the "central gneiss" suddenly expands to a great width of outcrop as the "Kund Kaplás" is neared.

My route now leads back over the Padri[1] pass. The rocks seen *en route* are slates, and on the ascent of the pass they are quite typical "Simla slates;" dip, N.-E. 5° N.

About two-thirds of the way between Thanala (Tenala) and the top of the pass (elevation of top 9,700′), I encountered my old friend, the "Blaini conglomerate." It is quite typically developed, and the detailed description given of it in my paper on the Dalhousie and Pángi section applies equally well to the rock seen in this section. On the conglomerate there rests, 975 feet below the summit of the pass, about 50 or 60 feet of pale-blue limestone. Above the limestones slates re-appear.

On the descent of the pass, going east, the slates are vertical, or nearly so, having a very high dip, sometimes in the normal, or north-easterly direction, and sometimes in the reverse direction. This variable underlie prevails, along the line of strike, in an easterly direction, as far, at any rate, as Manjir.

The conglomerate re-appears on the road side, about half a mile below the top of the pass. It runs thence to near Langera (Langaira), almost in a line with the road, cropping up on the road side more than once. Near Langera the outcrop is of great thickness.

Where the road, near Langera, descends to within a few yards of the river, the conglomerate contains a boulder of granitoid gneiss 1′ 3″ long. Mr. Lydekker has already noted the presence of granitoid gneiss[2] boulders in the slates of the Pángi-Lahoul valley; and the discovery of a similar boulder in the silurian conglomerate, on this side of the snowy range, is interesting and important.

I saw numerous blocks of pale-blue limestone, weathering buff, in the vicinity of the conglomerate, between the top of the pass and Bhándal (Baundal), but I doubt if any of them were *in situ*. They probably indicate the presence of the carbo-triassic series in the mountains which bound the north-eastern side of the Siul[3] valley.

The conglomerate continues in the same general direction as the river the whole way to Bhándal. I counted ten outcrops of it, *in situ*, on the road side, between Langera and Bhándal. Some of these outcrops run with the road for a considerable distance.

[1] This word is not Pádri, but Padri, which means flat.

[2] The presence of granite, or syenite, boulders in the conglomerate at Gurais, in Kashmir, is also noted by Mr. Lydekker at p. 24, Vol. XII, Records.

[3] Kundi Marál (Kandi Marl), the name entered on the map, is not the name of the valley, as one would suppose, or the name of the river that runs through it, but the name of an encamping ground, where the peg to which a Raja's horse was tied is said to have grown miraculously into a big tree. Hence the name.

A calcareous band (weathering buff [1]) crops out about 4 miles to the S.-E. of Prangal (Prungli), and re-appears several times afterwards.

To the east of Bhándal the conglomerate runs with the road for some distance.

It will, perhaps, conduce to clearness, if I note in this place the several outcrops of this rock which I have, up to date, noted along the line of its strike in an easterly direction. On the ascent of the ridge between Dihur (Duire) and Manjir, the conglomerate crops out on the road side, and, crossing the ridge with the road, descends to the river between Manjir and Kandla.

In my paper on the Dalhousie and Pángi section, I did not note the occurrence of the conglomerate on the left bank of the river to the east of Manjir, as, owing probably to the predominance of vegetation, I did not see any outcrop *in situ;* but the conglomerate, I doubt not, in its eastward extension, passes somewhere in the neighbourhood of Balore.

I came across another good outcrop of the rock in the mouth of the Hulh (Hul) valley, (immediately north of Chamba), between the villages of Baroar and Chambi. Proceeding eastwards from Chamba up the Ravi river, the conglomerate again appears on the road side at the bend of the river, a little to the east of Gun (Gnar). It continues thence in a nearly straight line to Chitráli (Chitralri) and Sowala, and curving round above Naukula, it passes a little above Aulansa (Hulans), and thence a little to the north of Grima, onwards through Suchai and Bauri (near Barmaor) to Poulda and Kund.

I have noted numerous outcrops along the line indicated, but it seems needless to describe them in detail. The country between the outcrops near Manjir and in the Hulh valley, and between the latter and Gun on the Ravi, I have not yet explored. I have, also, not been to the east of Harser, as the route I followed took me towards the sacred lake of Man Mhaish (Manimais).

It is interesting to note the continuous outcrop of the upper-silurian conglomerate along a line parallel to the granitoid gneiss, as it confirms the conclusion previously arrived at, that we have in the Dalhousie-Chamba section a normal sequence of silurian rocks resting on the granitoid gneiss.

Between Chamba and Dancho the dip is north-easterly. Near Harser, the dip, which had previously been moderate, becomes vertical, but between Harser and Dancho it again subsides into a N. E. dip.

Between Chamba and Mahila (Maila), the granitoid gneiss crosses to the right bank of the Ravi, at the bend of the river under Tandola, re-crossing to the left bank near Bania. It passes to the right bank, again, beyond Bania, and then continuing its course under Dalgara and above Korauh, it finally leaves the river near Mahila.

At the junction of the granitoid gneiss and the slates, the former is granitic and the latter is indurated, and sometimes silicious and massive. Under Dangera (Dalgara), near the junction of the two rocks, the slates are contorted, and there is a sudden reversal of dip, with more or less local faulting. At the actual

[1] Blue limestones, weathering buff, is a peculiarity which appears to be common to several bands of the carbo-triassic series and the Blaini limestone. It does not help to distinguish the two series.

junction the dip of the slates is normal. The plane of division between the schistose slates and the granitoid gneiss is not sharp, but the granitoid gneiss appears to be blended into the slates by imperfect intrusion.

I now ask the reader to return with me to Chamba, and accompany me up the Hulh valley.

Up to the outcrop of the conglomerate, between Baraur and Chambi, the rocks are silurians and the dip normal. After Chambi, the path (there is no made road, and consequently no good road-side sections) lies along a fertile and well-wooded valley. Vegetation is rich, and rocks, *in situ*, are only to be seen here and there. I saw no outcrop of limestone.

A little to the north of Hulh, I came upon trap resembling the Dalhousie rock, and it extended to about the level of Bhaloth (Balote). As I am not, at present, sure whether this outcrop of trap occurs to the north or to the south of the carbo-triassic series seen in force south of Kalel (Kalail), on the Chamba and Tisa road, I reserve further remarks on this section until I can explore the mountains round the Rundhurst station.

My route now lay up the Hulh valley, over the high ridge at its head, and thence down to Kalel. I was able to trace the boundary of the carbo-triassic series and the conglomerate. The latter runs a little to the north of Sairu, and continues parallel to the river, striking towards the ridge that terminates at the bifurcation of the stream. Numerous blocks of typical conglomerate fill the bed of the stream.

The section from Kalel to Tikri has been already described. My route now lay from Tikri to Himgiri (Himgir), and thence round the Himgiri station to Digi and Dihur, and back again along the river to Himgiri. The rocks about Tikri are silurians—micaceous schistose rocks, crumbling to a whitish soapy powder.

The northern boundary of the conglomerates runs a little south of Tikri (not the village above alluded to, but another village of the same name under Himgiri), and thence to Laura towards the Himgiri station, which it leaves a little on its right. The southern boundary of the conglomerate crosses the ridge west of Kalel at Dhar, and continues thence up the Gulel (Gulail) valley. I met with typical outcrops of the rock on the ridge east of Bila (under the Himgiri station), and again along the ridge above Gulel. I found another good outcrop on the ridge between Gulel and Tiloga.

The dip is normal until Himgiri is neared, when a S.-S.-W. dip sets in. To the west of Himgiri, this changes to a S.-W. 11° W. dip, and then becomes nearly perpendicular. Beyond this, the dip reverts to the N.-E. Further on, it becomes high and wavers occasionally to the south-west, but eventually settles down to a N.-E. dip.

In contact with the conglomerate, a trap, similar in its general appearance[1] to the Dalhousie rock, crops up along the ridge dividing the Gulel from the Tiloga valley. The outcrop is of considerable thickness, and in its S.-W. extension

[1] I have not as yet examined thin slices of it under the microscope.

it dominates the ridge running down to Dihur, in the neighbourhood of which village it either dies out or is cut off by a fault. The outcrop appears to widen in its northerly extension, and it is evidently present in force along the high ridge N. E. of Bhandal, the streams flowing down from which are full of boulders of trap. The western boundary of the trap runs a little to the east of the villages of Tiloga, Baroga, Kalsara, and Chikotra.

Following the road from Dihur to Himgiri, I found that where the road crosses it the outcrop is still of considerable width. It crops out at no great distance from Dihur, and extends to near the village of Dalui. On following a low-level path, near the river, as far as the stream to the north of Banjwar, however, I found that the trap does not extend as far east as this village.

Along the south-western boundary of the trap, the latter is in sharp contact with the limestones of the carbo-triassic series. This is well seen on the road leading from Dihur to Himgiri, where the limestones, which dip about N. N. E., are in great force. Both the trap and the limestones are typically developed, and the latter do not appear to be at all altered at their junction with the trap.

The limestone series is also well seen along the crest of the ridge north of Manjir. It crops out a little south of Nandla, and extends as far as Dhar. The dip, which is variable when the limestones first appear on the crest of the ridge, soon settles down to a N.-E. 5° N. dip. Some of the limestones are pale-blue, some creamy-white, and a few are of a deep dark-blue colour. Some of them weather to a rusty buff. I saw numerous blocks of limestone along this ridge crowded with crinoid stems, but I did not observe any *in situ*.

In connection with the trap above described, a variety occurs, which I have not observed elsewhere in the Himalayas, but which probably represents the porphyritic trap of Kashmir described by Mr. Lydekker. It is a felspar porphyry, an intensely hard rock; so hard that it was with extreme difficulty that I could obtain hand specimens of it. Boulders of it are brought down by the stream from the ridge N. E. of Bhándal, together with boulders of the ordinary variety of the trap. I have not yet seen it *in situ*.

Conclusion.—The observations made this season confirm the conclusion previously arrived at, that we have, in the Dalhousie-Chamba section, a normal sequence of silurian rocks resting on the "central gneiss." The "Blaini" conglomerate (upper-silurian) and the "Simla slates," of the Simla region, are both represented in Dalhousie-Chamba area; the conglomerate cropping out in a continuous line parallel to the granitoid gneiss.

The upper-silurian conglomerate is followed, in the Bhándal-Dihur region, by the carbo-triassic series, resting apparently conformably on it; but if the view taken of the age of the trap in the Dalhousie area in my paper on the geology of that region is sound, the boundary between the two series must really be a faulted one. The thinness of the conglomerates on the south side of the carbo-triassic limestones, as compared with their great development on the northern side of the limestone outcrop, is a fact which, to some extent, favours the fault hypothesis.

In the Bhándal-Dihur area, under consideration, the carbo-triassic limestones are followed by trap, and the latter by the upper-silurian conglomerate and a normal sequence of silurian rocks in inverse order.

In the Dalhousie area, the trap comes in between the carbo-triassic series and the tertiary rocks. In the Bhándal-Dihur area, it comes in between the carbo-triassic series and the upper-silurian conglomerate.

In my paper on the geology of Dalhousie, I adopted the hypothesis that the trap is of upper-silurian or pre-carboniferous age. I see nothing in the facts recorded in this paper inconsistent with that hypothesis. Indeed, I may say that when I formed my views regarding the age of the trap, I had distinctly before my mind's eye the possibility that trap might be found in the Bhándul-Dihur area, where I have since found it. I thought this possible from the fact that the Siul river under Manjir is full of trap boulders.

In both the Dalhousie and the Bhándal-Dihur areas the trap is found in contact with the carbo-triassic series; whilst in the latter section, it is in sharp contact with the upper-silurian conglomerate on the one side, and the carbo-triassic limestones on the other.

The fact that, in the Bhándal-Dihur section, the trap does not occur between the carbo-triassic series and the upper-silurian conglomerate, on both sides of the limestone outcrop, may I think be explained by the hypothesis of a fault between the limestones and the southern outcrop of the conglomerate.

The Bhándal-Dihur section, from the granitoid gneiss, south of Bhándal, to the lower-silurians, north of Bhándal, seems to me to be a crushed synclinal fold, complicated with faulting. That there is a fault somewhere seems self-evident. Whether the trap is of pre-carboniferous or of post-carboniferous age; in either case there must be a fault between it and the upper-silurian conglomerate.

The simplest mode of explaining the section, it seems to me, is to put a fault between the southern boundary of the limestone outcrop and the southern outcrop of the conglomerates; we should then have a normal ascending series of rocks from the "central gneiss" to the upper-silurian conglomerate, and a descending series of rocks from the carbo-traissic limestones to the lower-silurian schists. In short, I believe that we have in this section a crushed synclinal fold, with a fault along its axis, the compression of the folded strata having been great enough to produce a general conformity of dip.

In the Hulh section, I have some grounds for suspecting that the trap occurs between the southern outcrop of the conglomerate and the carbo-triassic limestones; but should this surmise prove correct, the point is immaterial as far as the hypothesis above propounded is concerned.

The observations made this season show that the outcrops of trap are not continuous; but whether this is due to faulting or to thinning out, I am not at present in a position to say. Either supposition seems equally probable.

The discovery of a boulder of granitoid gneiss in the upper-silurian conglomerate of the Bhándal region, taken in connection with the discovery by Mr. Lydekker of similar granitoid gneiss boulders in the silurian slates of the Pángi-Lahoul area, is another indication of the connection between the rocks of the two regions;

and, on the supposition that the granitoid gneiss boulders were derived from the "central gneiss," which Mr. Lydekker apparently does not now doubt[1], the fact supports the conclusion I arrived at for the Simla area, that a hidden unconformity exists between the silurian and the "central gneiss" series. A similar conclusion was drawn by Mr. Lydekker in his fifth paper on the geology of Kashmir.[2]

On the Basalts of Bombay, *by* COLONEL C. A. MCMAHON, F. G. S. *(with two plates).*

During my last visit to Bombay, I made a carefully selected collection of typical specimens of the lavas exposed at different parts of the island, and I have since studied thin slices of them under the microscope.

I think it will be worth while to give a brief description of these; partly as the first contribution towards a better knowledge of the Deccan traps, regarding which our petrological information is at present very deficient; and partly because the description of the very typical lavas of Bombay may be useful as a standard with which to compare more doubtful basic igneous rocks in other parts of India.

I arranged the specimens which I am about to describe with sole reference to their colour. They range from iron black through less and less dark shades of grey to a greenish-grey colour.

In specific gravity the specimens vary very little, ranging from 2·80 to 2·85, their average being 2·82. They are all remarkable for the absence of olivine. Augite, plagioclase, and magnetite are present in each slice. All contain a few crystals of sanidine, but it occupies an extremely subordinate position.

No. 1.—*A dark-grey, almost black, compact rock.* Sp. G. 2·82.

M.[3]—This slice consists of a net-work of very small felspar prisms, and minute granules of augite, starred about in a partially devitrified glassy base, with moderately large crystals of felspar and augite sparsely scattered through it. The base is brownish-grèen, dappled with white, in reflected light, and olive-green in transmitted light. The white opaque material is, I think, leucoxene, a secondary product resulting from the decomposition of ilmenite, though in the particular slice there is no direct evidence of its connection with that mineral.

The felspar prisms, for the most part, present very sharp outlines, and the great majority of them are seen to be triclinic. They contain numerous glass cavities, many of which have fixed bubbles. Some of these glass enclosures are elongated, others are in rounded forms. The presence of such cavities is considered by Dr. Sorby to indicate the true volcanic origin of the rock containing them (Q. J. G. S. XXXVI, 49, 53). In one of the prisms, the glass enclosures have ranged themselves roughly in a zone conforming to the shape of the prism. Other prisms contain portions of the glassy base caught up in them.

[1] Records, XIV. 42. [2] *Ib.*

[3] In this and following papers M stands for microscopic aspect.

Augite crystals are extremely abundant, and most of them are of very minute size. Among the larger crystals twinning is common, and some are well shaped. In transmitted light the augites exhibit a faint tint varying from greenish-yellow to yellowish-brown, but so faint as to be almost white. This is the predominant colour of the augite in all the slices.

The augite and felspar appear, on the whole, to have crystallised at the same time, though some individuals have formed before the others. In fig. 1, plate II, I have given a sketch of a couple of augite crystals of irregular shape, joined together in a manner suggestive of twinning, which have formed round a felspar prism; whilst in fig. 2, plate II, I have depicted a group of triclinic felspar prisms, which have formed upon, and partially enclosed, a cracked augite crystal.

The augite and felspar in this slice are remarkably fresh. This is a characteristic of the augite in all the Bombay slices.

Magnetite is present in some abundance, both in regular shaped crystals and in the skeleton forms described in my paper on the Darang traps. Some titanic iron (ilmenite) appears to be also present.

In fig. 1, plate I, I have given a sketch of a portion of this slice, as seen in the field of the microscope, under a magnifying power of 60 diameters. The outline of the felspar crystals is generally sharp,—an indication I think that the lava was in a very fluid condition. Towards the centre of the field a rather large augite crystal is represented. On three sides the prismatic faces may be traced, though they are not well depicted; whilst the crystal may be seen to be traversed by rather irregular prismatic cleavage lines. Cracks are sometimes of use and furnish indications, in a general way, of the direction of the cleavage. A large crack in the crystal under consideration affords an illustration of this. For some distance it follows the direction of one set of cleavage lines, and then changing its course follows the direction of the second set, which crosses the first at an angle (87° 5′) approximating that of a right angle.

A crack traverses the slice and appears to have been filled up by an exfiltration process; the material it contains being cryptocrystalline.

No. 2.—A compact, dark-grey, almost black rock, closely resembling the last
Sp. G. 2·82.

Under the pocket lens it has a somewhat vitreous lustre, and small facets of felspar are to be seen in it here and there.

M.—This slice is so like the last one that it hardly requires a separate description. The glassy base is whitish in reflected, and brown in transmitted light. Here and there it has been altered to a dull olive-green substance, which, when a single nicol only is used, transmits little light. In places it is stained brown-yellow to orange colour,—a result doubtless of the decomposition of magnetite.

Felspar is even more abundant than in the last slice; and here and there crystals of it are of comparatively large size. Glass and stone cavities are common in the felspar, but I discovered no bubbles in them.

Augite is fairly abundant. Its shape is irregular, but twinning is common.

Magnetite is very abundant, both in regular crystals and in skeleton forms in the glassy base. In the latter, as in the case of the augite in the pitchstones of Arran[1], the crystallization of the magnetite has resulted in a sort of halo being formed round the crystals,—the latter having in the act of crystallization drawn the colouring matter out of the base, leaving a comparatively colourless glass in their immediate vicinity.

No. 3.—A dark-grey, almost black, compact rock. Sp. G. 2·83.

M.—This slice consists of a profusion of augite, felspat, and magnetite crystals, scattered about in a glassy base.

The magnetite crystals are of good size, and are fairly well formed. The felspar and augite crystals are of two sizes; in the case of both minerals the majority are of small size (the augites being very minute); whilst here and there are others of comparatively large size. The majority of the felspar prisms are distinctly triclinic. Many of the augites are twinned.

Stellate groups of felspar, similar to those described in my paper on the Darang traps[2], are to be met with in all the Bombay slices. One of them from this specimen is shown in fig. 3, plate II, and another from No. 8 is given in fig. 10, plate II. The latter, which is quite accurately drawn, looks like a cross seen in part profile.

In my paper on the Darang traps I noted how crystals are often cramped at the time of their formation by adjoining crystals. In fig. 4, plate II, I have sketched a twinned augite which has attempted to crystallize in the midst of a perfect barricade of felspar prisms, and its outward symmetry of form has consequently suffered considerably. In such cases, however, though the external shape is deformed, the plane of twinning almost invariably exhibits a rigid straight line, and the internal symmetry, on which the optical properties of the mineral depends, sustains no injury.

In J. D. Danas' Manual of Mineralogy (1873), p. 152, augite crystals are said to be "usually stout and thick, and none have the slender bladed form common with hornblende." In lavas, however, as seen under the microscope, augite crystals sometimes take the form of acicular microliths, and not unfrequently assume the form of elongated prisms. A prism of this character occurs in the slice under consideration, and is represented in fig. 5, plate II.; (*a*) (*d*) is a long prism of augite which has grown up side by side with one of triclinic felspar. From (*c*) to (*d*) the augite is twinned, the twinning plane running with the length of the prism. From (*c*) to (*a*) the prism is made up of a crystal not in optical continuity with either of the twins below it. The augite in the course of its formation has enclosed the ends of small felspar prisms, which may be seen sticking, like parasites, into its side. The adjoining felspar prism appears to have grown tranquilly by the side of the augite up to (*b*), when the supply of felspathic material appears to have been less plentiful than that of the constituents of the augite and magnetite (three crystals of which are indicated at this point), and its

[1] Allport. Geological Magazine, Vol. IX, p. 2.
[2] *Supra*, Vol. XV, p. 155.

symmetry was greatly marred by the intervention of crystals of augite and magnetite (*b*). The ill-shaped felspar at the top (see sketch) is no doubt a portion, or what ought to have been a portion, of the prism seen below. The molecules of felspathic matter did their best, I take it, to keep the alignment of the felspar prism, and they are in optical continuity with it, but the augite and magnetite crystals got in the way, and the shape of the felspar prism was marred.

This, and the previously noted illustrations, will, I think, enable us to understand how the external symmetry, and the regular development of crystals in an igneous rock, are seriously interfered with by the contemporaneous formation of other minerals in close proximity to them, or by the presence and pressure of previously formed crystals.

No. 4.—A dark-grey compact rock. Sp. G. 2·82.

M.—The felspar and augite crystals are set in a glassy base, which is sufficiently abundant to entitle the rock to be classed as a magma basalt. The base is, for the most part, of light vandyke-brown colour, but is here and there altered to a substance olive-green in transmitted light. The base is crowded with microliths of magnetite in its rod-like form; it occurs also in large and rather well-shaped crystals and as a fringe round augite.

Almost all the felspar is visibly triclinic, and radiating groups are common.

Augite is very abundant, and very fresh, but its outward shape is rarely good and never perfect. Twinning is common, and the intersection of the prismatic cleavage lines is sometimes well seen.

In fig. 2, plate I, I have given a representation of a portion of this slice. Some of the felspar crystals therein figured present sharp and characteristic outlines; others again are very irregular. On the right hand of the illustration, two augite crystals are seen embracing two curiously shaped crystals of felspar. To the left also a large block, formed of a congeries of shapeless augite crystals, has more or less enclosed a radiating group of very irregularly shaped masses of felspar.[1] The partial enclosure of felspar by augite is very common in these slices, especially in the one under consideration. This, and the enclosure of augite by felspar noted in connection with slice No. 1, seems to indicate that the lava was at first in a very fluid state, in which free molecular action was possible; but that it cooled with such rapidity that the minerals were unable to disengage themselves from each other, and their crystallization was arrested before the symmetry of their external form was complete. Small peculiarities of structure of this kind are, I think, of value. The volcanic origin of the Bombay basalts being well known, structural characters observed in them may aid us to interpret rocks of more doubtful character in other regions.

Professor Geikie, in his paper on the Carboniferous Volcanic Rocks of the Basin of the Firth of Forth,[2] has described similar instances of felspar prisms

[1] Some of these seem to approach those "*complex fan-shaped brushes*" which Dr. Sorby describes as forming the terminations of felspar prisms in artificially melted rocks, and which he met with in a natural rock from a dyke near Beaumaris. Opening address, Geology Section of the British Association, 1880.

[2] Transactions, Roy. Soc., Edinburgh, Vol. XXIX, p. 437.

"shooting" through crystals of augite, and severing the augite into two parts in such a way that "not uncommonly it might be supposed to have been penetrated across its figure by intrusive prisms of felspar;" an appearance which Professor Geikie attributes to augite having "formed round and enclosed the already completed net-work of triclinic felspar prisms."

These partial enclosures of the one mineral by the other are described as occurring in the rocks which he classes as diabases and dolerites. The latter term he proposes to restrict to intrusive sheets and dykes which consolidated beneath the ground, retaining the word 'basalt' for interbedded augitic lavas which consolidated at the surface.

It is to be noted, however, that a glassy base does not appear to be entirely absent from either Professor Geikie's diabases or dolerites; and although I do not intend to infer from the preceding remarks that the intersection of small or moderate-sized crystals of augite by prisms of felspar, or of felspar prisms by augite, is an exclusive characteristic of rocks which have consolidated at the surface of the earth's crust; or that it would enable us to distinguish the latter from intrusive sheets or dykes; still, it is a structural peculiarity of basic volcanic rocks which is worth noting, and it may help us to distinguish basic lavas from basic plutonic rocks. Acid igneous rocks have characteristic features of their own.

The slice under consideration is of larger grain than any of the preceding ones.

No. 5.—A dark-grey compact rock. Sp. G. 2·83.

M.—This is a very fine-grained rock, and so closely resembles those first described that a detailed account of it is not necessary. The magnetite is well formed. The augite is for the most part very small, and twinning is common in the larger crystals.

At fig. 6, plate II, I have sketched an illustration of the way the formation of minerals went on side by side, in these Bombay basalts, at almost the same time. The illustration represents a crystal of magnetite and two crystals of augite. The growth of the lower augite and that of the magnetite appears to have gone on side by side, and, at first, at very much the same pace. The magnetite then gained on the augite and finally partially surrounded it. The formation of the second augite then began and went on so rapidly that it enclosed a portion of the magnetite in its embrace.

No. 6.—A perfectly compact dark-grey rock with a dull green tint in it. It weathers brown. Sp. G. 2·80.

M.—This is a fine-grained magma basalt. The base consists of a brown glass, here and there converted into a green amorphous substance. Augite crystals are abundant in this slice. Most of them are very minute, and, in polarised light with crossed nicols, they stand out from the black background like stars on a clear night. Some are of fairly large size. Twinning is common, and a few of the augites are well shaped.

Felspar is abundant and is chiefly in small prisms. Most of it gives decided evidence of belonging to the triclinic system.

Magnetite is for the most part well shaped and of good size, but it is also to be seen in elongated stalk-like microliths in the glassy base.

Fig. 7, plate II, is an illustration taken from this slice showing the way minerals, in the process of crystallisation, catch up, enclose, and become entangled with other minerals. An augite crystal is there seen to have enclosed several crystals of magnetite, and to have partially surrounded crystals of triclinic felspar; whilst other crystals of magnetite have formed on it.

The microscope enables one to understand how it is that the chemical analysis of minerals often yields such divergent results. Fig. 7, will, I think, suggest the explanation of how this takes place.

No. 7.—A compact greenish-grey rock. Sp. G. 2·85.

M.—The grain is larger than that of the preceding slices. Augite is abundant. Much of the felspar exhibits the twinning peculiar to triclinic felspar, and is in characteristic prisms. Felspar also occurs in large crystals and in shapeless masses, some of which are certainly sanidine.

The glassy base is of green colour. Here and there minute portions of it have been converted into delessite, and the whole of it is more or less changed. The rock is passing into the condition of the Darang traps (*l. c.*). In these slices, however, the glassy base can still be distinctly recognised as such. Very little magnetite is left in the rock.

At fig. 3, plate I, I have given a sketch of a portion of this slice. The very dark portion is the glassy base. The less dark portion is augite, and the white is felspar.

At fig. 9, plate II, I have sketched a group of augite crystals in polarised light under crossed nicols. It is impossible, in simple black and white, to indicate the various colours in which the crystals polarise; but the different shades of black will, perhaps, suffice to show the want of optical continuity between the different members of the group. The two small crystals at the upper left hand are seen to be twinned, the twinning plane being a sharp straight line, and the two halves of each twin polarising in complimentary colours. The others are crystals of different sizes and of very irregular shape. The various crystals of which this and similar groups are composed, began to crystallize, apparently, much about the same time from independent centres, and from want of space interfered with each other's growth and development. One micro-augite is enclosed in a large crystal, whilst another augite contains a gas bubble.

The group appears to have been rapidly formed, for along the upper margin a tongue of the glassy base (*a*) is partially enclosed in it.

I have depicted another characteristic group in fig. 8, plate II, taken from slice No. 10. One augite crystal, at the right hand, is seen to be nearly surrounded by a larger crystal of the same mineral. The shapes of all the members of the group are very irregular, and they have evidently interfered seriously with each other's development. The finishing off of the group has been hurried in its last stages, as along the outer margin a zone of cavities is to be seen,—a not uncommon feature in the augite of volcanic rocks. These cavities, the irregular shapes of the crystals, and the confused association of imperfectly formed augites, are, I think, indications of the rapidity with which the rock cooled.

The large felspar crystals are not at all homogeneous in their internal structure, and they enclose irregular-shaped augite crystals and patches of viridite.

No. 8.—A greenish compact rock. Sp. G. 2·4.

M.—This slice very much resembles the last. The glassy base has been converted into a greenish substance which contains in it minute embryonic crystals of epidote. Alteration has been set up in the felspars. Magnetite is not abundant, and is mostly in skeleton forms.

No. 9.—A greenish-grey compact rock. Sp. G. 2·85.

M.—In this slice augite is very abundant. The glassy base is still recognisable, but it has passed into an alteration product, olive green in transmitted light, which is in part, at any rate, delessite. A radiating structure is often apparent in it, and all of it is feebly dichroic when the polariser alone is used.

This slice contains a good many sanidine prisms exhibiting the simple twinning of the Carlsbad type, but they are quite subordinate to the plagioclase.

In one case water has clearly gained access to the rock, and a thin undulating ring of quartz has been left behind to mark its passage.

Augite crystals often partially enclose crystals of felspars, and felspars occasionally enclose fragments of the glassy base.

No. 10.—A grey compact rock. Sp. G. 2·81.

M.—The glassy base is still to be seen here and there, but in most cases it has been replaced by delessite, and in a few cases by chalcedony. It gives clear evidence of the invasion of water. The latter has often left castellated watermarks behind it, and has partially rounded the margins of the channels through which it flowed, so that in some cases these altered portions of the base have the appearance of amygdules plugging amygdaloidal cavities. I think that the results above described may be accounted for on the supposition that the uncrystallized glassy base yielded more readily to the solvent powers of heated water than the minerals that had crystallized out of it.

It is important to note the tendency, here evidenced, of acid water passing through a rock to excavate *rounded* cavities; the removal of olivine and leucite, and the rounding of the edges of the matrix in which they were buried, might lead to the formation of a pseudo-amygdaloid, and prevent the secondary minerals, substituted for olivine and leucite, being recognised as pseudomorphs of those minerals.

The felspar is more or less altered, but the augite is quite fresh. The slice contains some prisms of sanidine which exhibit characteristic Carlsbad twinning.

No. 11.—A greenish-grey compact rock. Sp. G. 2·81

M.—This slice closely resembles the last. The magnetite or titaniferous iron is a good deal decomposed, and much of it has passed into leucoxene. A study of these slices confirms the view taken of the origin of the opaque white material formed in connection with the Darang basalts. The white opacity diffused in a nebulous way through the latter is, I think, due in many cases, not to the decomposition of large regular crystals of ilmenite, but to the minute dendritic forms of iron disseminated through the base.

This rock generally is passing into a stage of alteration like that described in the traps of Darang (*l.c.*)

Conclusion.

I have not detected olivine in any of these slices either fresh or in an altered condition.

Olivine, though a very characteristic mineral, usually present in basalts, does not appear to be universally so abundant as to be invariably visible in every thin slice made for microscopic examination.

Forchhammer states that it does not occur at all in the basaltic rocks of the Faroe Islands;[1] whilst Professor Geikie, in his paper on the microscopic characters of the basalts of the Firth of Forth,[2] notes that it "varies much in quantity;" and though it is "usually discernible in every thin slice," in some basalts it appears only in occasional "rare and small pieces" Zirkel notes (Microscopical Petrography of the Fortieth Parallel, p. 219) that in rocks "closely allied" to the "proper or genuine felspar (i.e., plagioclase) basalts," and which he classes as a sub-division of the basalts, olivine is generally wanting. In some of the Deccan traps from other localities, specimens of which the Superintendent of the Geological Survey of India has kindly allowed me to see, it is very abundant. Olivine may possibly not be altogether absent from the Bombay lavas; but, if present, it must be sparsely disseminated through them.

In view of the absence, or sparseness, of olivine, the question arises whether these rocks should be classed as basalts at all. In mineral composition they approximate closely to the quartzless-augite-andesites, in which olivine is rarely met with.[3]

The specific gravity of andesites ranges from 2·70 to 2·85; whilst the Bombay lavas, judging from the specimens now described, range from 2·80 to 2·85. In view, therefore, of the absence of olivine, a good case might be made out for classing the Bombay rocks with augite-andesites rather than with basalts.

But, on the whole, it will, I think, be better to retain the name by which the Bombay rocks have hitherto been known, and to continue to call them basalts; for I think it will conduce to clearness and simplicity if we restrict the term 'andesite' to the lava form of diorite and retain the words 'basalt' and 'dolerite' for basic augitic lavas. The term 'augite-andesite' seems a suitable one for intermediate forms between the two in which augite and hornblende are both present; and I prefer not to use it for the Bombay rocks because they contain no trace of the latter mineral.

As the Bombay basalts are very typical volcanic rocks, it may be useful, and may aid us to determine more doubtful rocks in other localities, to sum up the indications they afford of being superficial lava streams.

1 Bischof's Chemical Geology, II, p. 356.

2 *Loc. cit.*, p. 506.

3 Rutley's Study of Rocks, p. 236.

The following points, I think, afford evidence of rapid cooling, though some of them are more cogent than others:—

1. The presence of a glassy base.

2 Skeleton, dendritic, and rod-like forms, of magnetite and (?) ilmenite.

3. The presence of glass enclosures, and gas bubbles, in augite and felspar crystals [1]

4. The abundance of felspar prisms of small size, the longer axis of which usually points in all directions.[2]

5. The abundance of granular[3] and minute crystals of augite.

6. Clusters of irregular-shaped augite crystals.

7. Imperfectly-formed and feathery felspar crystals.[4]

8. The penetration of augite by felspar and of felspar by augite.

EXPLANATION OF PLATES.

PLATE I.

Figs. 1, 2, and 3.—Thin slices of Bombay basalts as seen under the microscope.

PLATE II.

Fig. 1.—Partial enclosure of felspar by augite.
Fig. 2.—Partial enclosure of augite by felspar.
Fig. 3.—Stellate prisms of felspar.
Fig. 4.—A twinned augite and felspar prism.
Fig. 5.—Augite and felspar prisms formed side by side.
Fig. 6.—Augite and magnetite formed at nearly the same time.
Fig. 7.—Augite enclosing magnetite and felspar.
Figs. 8 and 9.—Irregular-shaped clusters of augite crystals.
Fig. 10.—Another stellate form of felspar.

[1] Dr. Sorby, Ann. Address, Q. J. G. S. XXXVI, 58.

[2] Professor Geikie, in the paper already quoted, states that intrusive dolerite "along the line of contact with a sandstone or other granular rock" "becomes exceedingly close-grained," and the felspar prisms "tend to range themselves parallel with the surface of the sandstone."

[3] Professor Geikie, in the paper already quoted, writes of the volcanic rocks of the Firth of Forth:—"There is one distinctive feature between the mode of occurrence of the augite in the 'dolerites and in the interbedded anamesites and basalts which I have found to hold good with 'few exceptions. While in the intrusive sheets the augite occurs either in well-marked crystals or 'in large crystalline irregularly-shaped portions, in the superficial lava-beds it is commonly present 'in abundant small granules and in sparse definite crystals."

[4] See Dr. Sorby's opening address, Geology section of the British Association, 1880.

Fig 1 × 60

Fig 2 × 85

Fig 3 × 85

Reproduced in heliogravure from the original drawings at the Surveyor Generals Office, Calcutta
January 1883

Fig 1

Fig 2

Fig 3

Fig 4

Fig 5

Fig 6

Fig 7

Fig 8

Fig 9

Fig 10

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January 24th, 1883.

RECORDS

OF THE

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Part 2.] 1883. [May.

Synopsis of the Fossil Vertebrata *of* India, *by* R. Lydekker, B.A., F.G.S., F.Z.S.

INTRODUCTORY.

In the "Journal of the Asiatic Society of Bengal" for the year 1880 there appeared a paper by the present author, under the title of a "Sketch of the History of the Fossil Vertebrata of India," in which every species of fossil vertebrate animal then discovered in India was recorded, while there was also given a short summary of the labours of those palæontologists who had written on the Indian Fossil Vertebrata. Since the date of publication of that paper a great increase in our knowledge of the subject has been obtained, and it has accordingly been thought advisable to republish the substance of that paper, with such additions and alterations as are necessary to bring it up to the present state of our knowledge. In many instances these alterations have been so extensive as to have made it necessary to totally re-write a great portion of the original paper. It has been thought better to omit the introductory portion, in which the names of the chief workers in this field of enquiry are recorded, as there is no essential alteration to be made regarding them. Some introductory observations on the general relations of the Indian fossil vertebrates have likewise been omitted, as well as all the references. The record of the local distribution of species, and the places where the more remarkable specimens are preserved, form a new feature in this memoir.

The plan of the original paper has been in the main strictly adhered to; this consists in taking each of the classes of the vertebrata and recording their geological distribution, from the oldest to the present time. At the end a systematic synopsis of all the known forms is given, arranged according to their geological distribution; and also an alphabetical list of the species.

CLASS I.—PISCES.

Carboniferous.—The earliest fishes of which there is any record are known merely by a few specimens of teeth and dorsal spines obtained in the palæozoic rocks of the Salt-range in the Panjáb. The beds from which these remains were obtained are termed the "Productus-Limestone," and are considered to correspond roughly to the carboniferous of Europe. Among these fishes there is a new genus of ganoid described, upon the evidence of a single tooth, under the name of *Sigmodus dubius*; this tooth is of an elongated conical form, much resembling the teeth of certain Saurians. Of the *Cochliodontidæ*, here provisionally referred to the Ganoidei, there are two genera, each represented by a single species, namely, *Pæcilodus paradoxus* and *Psephodus indicus*; the tooth of the former is of the flattened cestraciont type. Of the Elasmobranchii, five genera have been named, some from the evidence of teeth, and others from spines; but, in view of certain modern discoveries, it is not impossible that in some cases distinct genera have been formed from the different remains of the same animal. Of these the new genus *Helodopsis*, allied to the European *Helodus*, has been formed for the reception of two teeth, which have been referred to distinct species under the respective names of *H. elongata* and *H. abbreviata*. A fragmental tooth, too imperfect for specific determination, has been referred to the common European carboniferous genus *Psammodus*. A fourth tooth, under the name of *P. indicus*, is referred to the European genus *Petalorhyncus*, which is very doubtfully separated from *Petalodus*. Of the spines, three specimens are referred to the genus *Xystracanthus*, of the carboniferous of America, under the names of *X. gracilis*, *X. major*, and *X. minor*; the possibility of these specimens belonging to some species of *Helodopsis* is, however, suggested. A fourth spine is referred to a new genus, under the name of *Thaumatacanthus blanfordi*. As far as the evidence of these fishes goes, it is apparent that sharks with crushing teeth were the dominant forms in the Indian carboniferous seas, as well as in those of Europe and America. All the specimens noticed above are in the collection of the Indian Museum.

From the same rocks there have been obtained teeth of two species of the elasmobranch genus *Acrodus*, to one of which the name *A. flemingi* has been applied. Other small teeth have been doubtfully referred to the ganoid genus *Saurichthys*, with the name of *S. (?) indicus*.

Trias-jura.—In the upper portion of the great Gondwána system, probably corresponding as a whole to the trias and jura, remains of fishes have been found in some abundance, the determined forms belonging to freshwater ganoids. In the Maleri group[1] of this system, the fauna of which shows a rhæto-triassic facies, three spines of the genus *Ceratodus* have been determined, and respectively named *C. hislopianus*, *C. hunterianus*, and *C. virapa*. The latter is considered to be closely allied to *C. polymorphus* of the rhætic of Bristol. At the present day the genus inhabits the rivers of Queensland, and in Europe is found fossil from the Keuper to the Jura. The specimens of the Maleri teeth are in the Indian Museum. From the Kota group, sometimes classed with the Maleri group, but showing a more distinctly liassic series of fossils, nine species of ganoids have been determined, belonging to the genera *Dapedius*, *Lepidotus*, and *Tetragonolepis*, all of which occur in the secondary strata of Europe, where they range from the lias to the eocene, *Lepidotus* being especially characteristic of the wealden. The majority of the specimens on which these species are founded are, it is believed, in the collection of the Geological Society, but there are a few in the Indian Museum;

[1] I follow the Director General of the Geological Survey of Great Britain and Ireland in continuing to use the term 'group' as subordinate to the terms 'system' and 'series.'—See Geikie: "Text-Book of Geology," 1882, p. 635.

in many cases they comprise nearly perfect fish. Bones, apparently of fishes, have been obtained from the trias of Tibet, but are too imperfect for determination.

Cretaceous.—A few remains of fishes have been obtained from the middle cretaceous Lameta group, but are not determined, though it has been suggested that some of them may belong to the genus *Sphyrænodus*, of the eocene and miocene of Europe. From the middle and upper cretaceous Trichinopoli series, seventeen species of Elasmobranchi have been described, belonging to the genera *Corax*, *Enchodus*, *Lamna*, *Odontaspis*, *Otodus*, *Oxyrhina*, *Ptychodus*, and *Sphærodus*, and one ganoid, doubtfully referred to *Pycnodus*; all these genera occur in the cretaceous of Europe, of which period some are characteristic. Two of the Indian species, *viz.*, *Corax pristodontus* and *Ptychodus latissimus*, are common to the cretaceous of Europe. Most of these species are founded on the evidence of teeth, some of which are in the Indian Museum and others in the collection of the Geological Society of London.

Eocene.—From the eocene of the Andaman Islands and Rámri Island on the Arakán coast, there have been obtained two teeth of a large *Diodon*, named *D. foleyi*; from the occurrence of *D. hystrix* off these coasts at the present time, it may be assumed that the genus has lived there since the eocene. Remains of a large species of this genus have been obtained from the miocene of Malta. Undetermined cycloid scales have been obtained from the eocene of Thyetmyo in Burma. From the eocene of the Panjáb there are other undetermined scales, and the dental plate of a species of eagle-ray,—*Myliobatis*,—a genus very common in the eocene of Europe, and widely distributed at the present day. From the neighbourhood of Kohát, in the Panjáb, from strata of eocene or lower miocene age, a single incisor of a sparoid fish, named *Capidotus indicus*, has been obtained. The genus was previously known only from the miocene of Vienna and Silesia, and is allied to the living *Sargus*. All the above specimens of teeth are in the collection of the Indian Museum.

Pliocene.—From the Siwalik series numerous species of fishes have been obtained, though severa lhave not been determined. Among the siluroids, we have a large skull in the Indian Museum (originally referred to a gigantic batrachian) belonging to the living species *Bagarius yarrelli*, of the larger Indian and Burman rivers. The British Museum has the anterior portion of the skull of a siluroid (labelled *Pimelodus*), belonging probably to a smaller species of the same genus; and a smaller but nearly complete skull in the same collection belongs probably to this species. The survival of a pliocene fish to the present day is a fact of much interest. The genus would seem to have been widely distributed in eocene times throughout the East, as a species has been described from the tertiaries of Sumatra under the name of *B. gigas*. The posterior half of the skull of a gigantic siluroid in the British Museum indicates another genus of this group. Palatal teeth of a third form of siluroid, from the Panjáb and Sind, and now in the Indian Museum, probably belong to the genus *Arius*, now inhabiting the rivers of India. Among the elasmobranchi a few teeth indicate a species of Siwalik *Lamna*, while a single tooth in the Indian Museum from Burma belonged to a small species of *Carcharodon* or *Carcharias*. Large squaline vertebræ, now in the Indian Museum, have been obtained from the Siwaliks of Perim Island.

From the tertiaries, or post-tertiaries, of the Káshmír valley a few fish-scales have been obtained.

CLASS II.—AMPHIBIA.

Trias-jura.—The oldest-known Indian amphibian is represented by a skull and part of the vertebral column, from the Bijori group of the Gondwánas, of a large species. This fine specimen belonged to the Asiatic Society of Bengal, and was sent to England for description about 18 years ago, since which time it has lain unnoticed. It has recently been recovered, and the writer hopes subsequently to give a description of it. The skull is of a triangular shape, and has been referred to *Archegosaurus* and *Labyrinthodon.* In its restricted sense, no skull is known of the latter genus, and it is quite possible that the Indian specimen may belong to *Mastodonsaurus* or to some other genus. Provisionally, it is convenient to refer to it as an *Archegosaurus* (see Note, p. 93)

From the Panchet group of the Gondwánas three genera of slender-jawed labyrinthodonts, allied to those of the European trias, are known. The first of these, *Pachygonia*, has only the one species *P. incurvata*, and is known by the greater part of the mandible, and a fragment of the skull. The marking of the former is like that of *Mastodonsaurus.* The second genus, *Gonioglyptus*, has two species, the smaller known as *G. longirostris* and the larger as *G. huxleyi;* it is considered to be closely allied to *Trematosaurus* of the bunter-sandstone of Germany. The third genus is known only by a single fragment of the mandible, to which the name *Glyptognathus fragilis* has been applied. These three genera are peculiar to India, and all their remains are exhibited in the Indian Museum; the two former belong to the group Euglypta.

From the Mángli beds of the Gondwánas, another peculiar genus of labyrinthodont has been obtained, and is represented by a single skull in the collection of the Geological Society, to which the name *Brachyops laticeps* has been applied. The genus is allied to *Rhinosaurus* from the jurassic of Europe, to *Micropholis* of the trias of Africa, and to *Bothriceps* of the trias of Australia, and with them constitutes the group Brachyopina.

From the Maleri group fragmentary jaws of a species of *Pachygonia*, probably the same as the Panchet form, have been obtained, as well as simple biconcave vertebræ of considerable size, probably belonging to a labyrinthodont; these specimens are in the Indian Museum.

Tertiary.—No amphibian remains have hitherto been obtained between the trias-jura and the tertiaries. In the lower series of the latter at Bombay there occur numerous remains of a small frog, belonging to the genus *Oxyglossus,* now living in China, Siam, and possibly India; the fossil species is extinct, and is known as *O. pusillus:* remains of a larger, but undetermined, frog are also indicated.

CLASS III.—REPTILIA.

Trias-jura.—The oldest reptiles hitherto found in India belong to the orders Dinosauria and Dicynodontia, and occur near Ráníganj in lower Bengal, in the Panchet group of the Gondwanas, probably of triassic age. The remains of a species of *Dicynodon*, belonging to the sub-genus *Ptychognathus*, which is of comparatively common occurrence in the coarse Panchet sandstones, and has been described as *D. orientalis*. Other remains seem to indicate a second and larger species of the genus. This order of reptiles seems to be characteristic of the trias of India, Russia, and Africa, and to have attained its fullest development in the latter country. The remains of the Indian forms all occur over a very small area in one thin seam of the Panchets. The Dinosaur has been named *Ankistrodon indicus*, and is the sole representative of the genus; it is known merely by two minute compressed and trenchant teeth with serrated edges like those of *Megalosaurus*, implanted in distinct sockets. The above specimens are in the Indian Museum. The Maleri group of the same system has yielded numerous, though much broken, remains of a large crocodilian, constituting the still undescribed genus *Parasuchus*, and bearing the manuscript specific name of *hislopi*, after the late Rev. Mr. Hislop, the discoverer of the vertebrate fossils of the Maleri group. This crocodile belonged to the amphicœlian division of the order, and seems to have been closely allied to *Belodon* and *Stagonolepis* of the trias of Europe, the three genera forming a group characterised by the non-union of the pterygoids behind the palatines. The scutes referred to *Parasuchus* differ from those of living crocodiles by their sculpture consisting of ridges and furrows radiating from a sub-central point, instead of isolated irregular pits. From the Denwá group of the same system a single scale of a gigantic crocodilian, probably belonging to the above genus, has been obtained. The Tiki beds in South Rewá, which are not improbably the equivalent of the Panchet group, have yielded other crocodilian remains, agreeing in the structure of the scales with *Parasuchus*, but distinguished by a totally different form of barioccipital, whence it is inferred that they probably belong to a distinct genus. In addition to the above, the Maleri and South Rewá rocks have yielded remains of a large species of the lacertian genus *Hyperodapedon*, originally described from the English trias. The Indian species, *H. huxleyi*, differs from the European, *H. granti*, by the greater number of the palatal teeth, and the presence of some additional teeth on the outer surface of the mandible; its length has been roughly estimated at 16 feet. The genus is closely allied to the living *Hatteria* of New Zealand, and has been supposed to have an affinity to *Rhynchosaurus* of the trias of Europe. From the Chári group of the jura of Kach there has been obtained a single crocodilian vertebra, not improbably belonging to *Parasuchus;* and from the Umia group of the same, a fragment of the mandible of a *Plesiosaurus*, described as *P. indicus;* the affinities of this form cannot be fully determined from the specimen.

The whole of the remains from the trias-jura, mentioned above, are in the collection of the Indian Museum.

Cretaceous.—From the Trichinopoli group (upper cretaceous), and probably from the Lameta group (middle cretaceous), there have been obtained a few teeth of a species of *Megalosaurus*, a genus whose range in Europe extends from the jurassic to the wealden; the one tooth of the Indian form now forthcoming is in the Indian Museum. From the Lameta series there have also been obtained the remains of another genus of gigantic dinosaur, to which the name *Titano-*

saurus has been assigned. This genus is allied to *Pelorosaurus* of the English wealden, and to *Ostiosaurus* of the jurassic, and was a long-tailed terrestrial form. The genus was represented by two species,—*T. indicus* and *T. blanfordi;* the former characterised by the centre of the caudal vertebræ being compressed, while in the latter they are sub-cylindrical. Numerous vertebræ, chiefly caudal, and a huge femur, nearly 4 feet in length, are preserved in the Indian Museum, and there is a cast of one of the former, belonging to *T. indicus*, in the British Museum. A few bones, in the former collection, indicate a smaller undetermined reptile from the Lametas.

The Chelonia are known in the cretaceous merely by some broken plates, in the collection of the Indian Museum, obtained from the Lametas, from the infra-trappeans of Rájamahendri (Rajamundry), and from the upper cretaceous of Sind.

The Crocodilia of the cretaceous are known only by one amphicœlian species, apparently allied to *Suchosaurus* of the English wealden, of which some vertebræ have been obtained from the upper cretaceous of Sind, and are now in the Indian Museum.

A large species of *Ichthyosaurus*, named *I. indicus*, is known solely by a few vertebræ obtained from the middle cretaceous of Trichinopoli, and now in the Indian Museum; the range of the genus in Europe is from the lias to the chalk.

Eocene.—The only specifically determined eocene reptile has been referred to the genus *Hydraspis*, under the name *H. leithi*. The specimen on which this determination rests is a carapace from the inter-trappeans of Bombay. The genus *Hydraspis* belongs to the *Emydidæ*, and is now confined to tropical America. From the nummulitics of the Panjáb numerous fragmentary remains of crocodilians have been obtained, but in too imperfect condition for determination.

Pliocene[1].—Many of the Siwalik chelonians in the British and Indian Museums are still undescribed, and the following list must, therefore, be considered imperfect. Of the Crocodilia, a species from the Sub-Himalaya and Perim Island has been identified with the living Indian *Crocodilus palustris (bombifrons)*, remains from Burma and Sind probably belonging to the same species. Of the genus *Gharialis (Leptorhynchus)*, a species from the Sub-Himalaya, Burma, Sind, and Perim Island is identical with *Gharialis gangeticus* of the Ganges and Jamna. A second species from the Sub-Himalaya, with slender teeth, has been named *G. leptodus;* and a third, of gigantic dimensions, and with shorter and stouter jaws and teeth, *G. crassidens;* the latter has been obtained from the Sub-Himalaya, Burma, and Sind. Remains of the above species are preserved both in the British and Indian Museums.

Of the order Lacertilia only one species of *Varanus* is known, and named *V. sivalensis:* this determination rests on the evidence of the distal extremity of a humerus, from the Sub-Himalaya, in the British Museum. The genus *Varanus*

[1] In this memoir the fossiliferous Siwaliks of Sind (lower Manchhars) are termed earlier pliocene, and those of the Sub-Himalaya and other parts of India higher pliocene,—the possibility of some of the Sind beds being of miocene age being still kept in view. The terms earlier and higher pliocene are intended merely to indicate that the one is older than the other, and not to indicate their correlation with the divisions of the European pliocene.

is now of common occurrence, and has probably existed since the oligocene, as the so-called *Palæoinranus* of the Quercy phosphorites is probably the same.

The Ophidia are known only by some vertebræ from the Panjáb and Sind, belonging to the genus *Python*, and not distinguishable from those of the living Indian *P. molurus;* these specimens are in the Indian Museum. A species of python (*P. cadurcensis*) from the Quercy phosphorites seems to have very closely resembled *P. molurus.*

The Chelonia are well represented, and comprise among other land tortoises the gigantic *Colossochelys atlas* from the Sub-Himálaya and Burma. This form is stated to be mainly distinguished from *Testudo* by the thickening of the episternal portion of the plastron, but it is doubtful if this character is of generic value, and the species should probably be referred to the latter genus. The length of the restored carapace in the British Museum is 12 feet 8 inches, and the entire animal, with the head and tail extended, is considered to have attained the length of 22 feet. In addition to this gigantic animal there is good evidence of the existence of other large tortoises, as the Indian Museum possesses several specimens of the ankylosed episternals of at least two species of large tortoises. These bones are as thick, but not as long, as those of *Colossochelys*, and their extremities are shorter, but more divergent; they probably belonged to species of *Testudo*, about two-thirds the size of *C. atlas.* A broken episternal indicates a third, but smaller species; while a fourth species of about the same size as the last is represented by three episternals in the Indian Museum, which are not bifurcated at their anterior extremities. A single carapace of a small tortoise in the Indian Museum seems also to belong to the genus *Testudo.* Among the hard-shelled emydine tortoises we have a species of *Bellia*, represented by two carapaces in the Indian Museum, which has been named *B. sivalensis*, and is considered to be closely allied to *B. crassicollis*, now inhabiting Tenasserim, Siam, and Sumatra; the genus is only represented by one other living species, *B. nuchalis* of Java. Another carapace in the Indian Museum, also from the Panjáb, seems to indicate a second Siwalik species of the genus. In the British Museum there are two carapaces of Siwalik land tortoises, with three dorsal ridges, which, although differing considerably in size, evidently belong to the same species, and since the smaller cannot be distinguished from the living *Damonia hamiltoni*, inhabiting Lower Bengal, they may be referred to that species; as is frequently the case, however, the fossil form greatly exceeded the living in size. The larger specimen was named *Emys hamiltonoides* in manuscript. An imperfect carapace from the Panjáb, in the collection of the Indian Museum, seems to belong to the genus *Emys.* A single marginal plate, also in the Indian Museum, has been referred, under the name of *Cautleya annuliger*, to a new genus, said to be distinguished from all other emydine tortoises by the cartilaginous, in place of the osseous, union of the marginals with the adjoining plates. Among the Bataguridæ, some carapaces in the British Museum indicate an animal identical with the living *Pangshura* (*Emys*) *tectum*, now inhabiting Lower Bengal; the fossil form attained a larger size than the recent. A large species of *Batagur* has been obtained in some numbers, but is not specifically determined. A carapace of this genus in the Indian Museum, with a ridge on the vertebral plates, very probably belongs to a second species. Remains of a large *Trionyx* are likewise not uncommon, but have not yet been specifically determined. A carapace in the British Museum has been identified with the living *Emyda vittata* (*ceylonensis*) of Central and Southern India and Ceylon, and it is probable that numerous other remains of this genus may be referred to the same species.

Pleistocene.—The reptiles of the pleistocene are still very imperfectly known, but it is probable that they all belong to living Indian species. From both the Jamna and Narbada beds specifically indeterminable remains of crocodiles have been obtained. Two complete specimens of the carapace of *Pangshura tectum* from the Narbada are in the Indian Museum, and serve to connect the living with the Siwalik form, and show that the range of the species once extended over the greater part of India. A portion of the plastron of a *Batagur* from the Narbada has been provisionally referred to *B. dhongoka*, now found in the same river. A fragment of the carapace of a *Trionyx*, from the same deposits, probably belonged to *T. gangeticus*, and it is highly probable that a large chelonian cranium in the British Museum, from the same deposits, should be referred to the same species.

General.—The foregoing notes will show that the fossil reptiles are very few in number, and that many are only known by very fragmentary remains. The known mesozoic forms belong entirely to extinct genera; the one known eocene reptile belongs to a genus still living, but now far removed from India; the pliocene forms (with the exception of the doubtful genus, *Colossochelys*) all belong to modern Indian genera, and frequently to existing species, although their range is now frequently restricted to the more southern parts of India; in the pleistocene it is probable that all the forms belong to existing species, which still inhabit the same districts as their fossil ancestors.

CLASS IV.—AVES.

Pliocene.—Remains of birds have hitherto been found only in the Sub-Himalayan Siwaliks, and in one instance in Sind; their numbers are still very small. Some of these remains are in the British, and the others in the Indian Museum. Among the carinates, a tarso-metatarsus has been considered to belong to a cormorant, and is provisionally referred to the genus *Graculus*. A species of pelican (*Pelecanus cautleyi*), somewhat smaller than the living Indian *P. mitratus*, is indicated by a fragment of the ulna; while another fragment of the same bone has been referred to a second species, under the name of *P. sivalensis*, but there is some doubt whether the generic determination is correct. A gigantic wader has been described, from the evidence of a sternum and tibia, under the name of *Megaloscelornis sivalensis*, and it is possible that the condyles of a humerus from Sind, measuring 2 inches in diameter, may belong to the same genus. A species of adjutant stork, which appears to have had considerable variations in size, has been named *Argala falconeri*. The Ratitæ appear to have been represented by three species, one of which was a true ostrich (*Struthio asiaticus*[1]), and is known by several bones of the leg and foot; and some cervical vertebræ. The second species is an emeu (*Dromæus sivalensis,*) and is indicated

[1] The name *S. palæindicus* occurs in manuscript.

by some toe-bones; while the third, which is not even generically determined, is considered to be a three-toed form, intermediate between the ostrich and the emeu, and is only known by one of the bones of the foot.

CLASS V.—MAMMALIA.

Eocene.—No traces of mammals have yet been detected below the eocene, and there only some very fragmentary bones have been obtained from the Panjáb. The determinable bones consist of the distal portions of the femur and the metatarsus of a perissodactylate animal, allied to, if not identical with, the palæothere and the astragalus of an artiodactylate. The latter was obtained above the nummulitic clays of Fatehjang, and belonged to a (probably) ruminant animal, in which the navicular and cuboid elements of the tarsus were united. These specimens are in the Indian Museum.

Miocene.—The only definitely determined miocene mammal is a rhinoceros from the Gáj beds of Sind, which is apparently a variety of *R. sivalensis*, and has been named *v. gajensis*.

Pliocene.—The primates are known merely by a few fragmentary specimens of upper and lower jaws, with their teeth, and by one bone. The palate of a female, and the upper canine of a male, have been referred to a large anthropoid ape, under the title of *Palæopithecus sivalensis;* the genus seems to be allied to the orang, but is distinguished by the narrower form of the premolars: this specimen is in the Indian Museum. The half of a palate, not improbably belonging to a species of *Semnopithecus*, in the British Museum, has been provisionally named *S. subhimalayanus*. A lower jaw and an astragalus, the former in the British Museum, seem probably to belong to a smaller form of *Semnopithecus*, considered to be distinct from the former species. A species of *Macacus*, larger than *M. rhesus*, is indicated by two fragments of the mandible, in the British Museum; while a second species, smaller than *M. rhesus*, and known as *M. sivalensis*, is represented by two fragments of the maxilla, with teeth, in the Indian Museum.

Among the Carnivora we find a large species of tiger, characterised by its greatly developed sagittal crest, which has accordingly been named *Felis cristata*[1]; this species is represented by three crania (and limb-bones) in the British Museum, to one of which the separate specific name *F. grandicristata* has been applied, but apparently on insufficient grounds. The Indian Museum possesses some limb-bones, and a lower carnassial tooth, which not improbably belong to this species. A smaller species of the genus, about the size of *F. bengalensis*, is indicated by a single ramus of the mandible, in the Indian Museum. The genus *Machairodus* is represented by *M. sivalensis* (*M. falconeri*, Pomel), apparently varying in size from the dimensions of the jaguar to those of the tiger, although it has been proposed to distinguish the larger form under the name of *M. palæindicus*. This species is represented by two broken skulls, and numerous fragments of the jaws in the British Museum, and by the hinder part of a small skull, and part of the mandible in the Indian Museum. The genus *Pseudælurus*, distinguished from *Felis* by the presence of three, or occasionally four,

[1] The manuscript name, *F. palæotigris*, exists.

in place of two lower premolars[1] (although the ante-penultimate premolar is occasionally present as an abnormality in *Felis*), is known by a ramus of the mandible, in the Indian Museum, named *P. sivalensis*; the species was about equal in size to a small leopard. Among the civet-like animals we have a species of *Viverra*, said to be closely allied to the living civet, and represented by two skulls in the British Museum, to which the name *Viverra bakeri* has been applied. *Ictitherium* is represented by *I. sivalense*, of which the two rami of one mandible, a broken ramus, without teeth, of another, and a canine tooth are known, all of which are in the Indian Museum, and came from the Panjáb. The hyænas are represented by *Hyæna sivalensis*, said to present relationship both to the Indian *H. striata* and to the African and European *H. crocuta*, of which there are numerous specimens of the skull and mandible in the British and Indian Museums. It has been proposed to separate some of these specimens under the name of *H. felina*, a so-called species said to be characterised by the absence of the first upper premolar, and by the minute size of the last upper true molar; a large series of specimens shows, however, a great variety in these respects. Remains of a species of *Hyæna* have been described from the pliocene of China, and referred to a distinct species. The dogs are represented by *Canis cautleyi*, and *C. curvipalatus*; the former closely allied to the wolf: portions of the skulls of these species are in the British Museum, and a specifically undetermined palate in the British Museum. The genus *Amphicyon*, distinguished from *Canis* by its plantigrade character and by the presence of an additional upper true molar, is represented by *A. palæindicus*, of which the Indian Museum possesses several specimens of the jaws and teeth from Sind and the Panjáb. The bears are represented by the genera *Ursus* and *Hyænarctos*: of the former there is a skull, without teeth, from the Sub-Himalaya, and a canine from the Irawádi, both in the collection of the Indian Museum. Of the latter there are two species, *H. sivalensis* and *H. palæindicus*. *H. sivalensis* has the molars with quadrangular crowns, and is known by a fine skull, the half of a mandible, and some limb-bones, in the British Museum; and by numerous specimens of the teeth and jaws in the Indian Museum; a single upper molar from the newer pliocene of England much resembles the teeth of this species. *H. palæindicus* is known only by a single maxilla in the Indian Museum, and is distinguished by the triangular form of the crowns of the upper molars, which approach those of *Amphicyon*. Of the subursoid carnivores, the genus *Mellivora* (*Ursitaxus*) is represented by *M. sivalensis*, known by a fragment of the mandible from the Panjáb, in the Indian Museum, and apparently very closely allied to the living Indian species; and the genus *Meles* by a single species, of which there is also only a fragment of the mandible contained in the Indian Museum. Of the otters, *Lutra palæindica* has been named from the evidence of a skull and lower jaw in the British Museum; and a second species seems to be indicated by a lower jaw from the Panjáb, in the Indian Museum. *Enhydriodon*, represented by *E. ferox*, is a genus peculiar to the Siwaliks; the only known specimens are two skulls in the British Museum, a part of the maxilla in the Museum of the Royal College of Surgeons, and a mandible. The genus takes its name from its

[1] Occasionally a tubercular true molar is present, and the genus then approaches *Proailurus*.

affinity to the living sea-otter (*Enhydras*). The living genus inhabits the coasts of the North Pacific during winter, and proceeds up the rivers in summer; but it is probable that its fossil ancestor must have been entirely a river-dwelling form.

The Proboscidia are very abundantly represented, species of all the known genera or sub-genera being present. The most specialised genus, *Euelephas*, is represented by *E. hysudricus*, of which the molars are of less complex structure than those of *E. indicus*. *Loxodon* is represented by *L. planifrons*, remarkable for being the only species of true elephant in which premolars are known to have been developed. The genus or sub-genus *Stegodon*, peculiar to South-Eastern Asia, is represented by four species. Of these the molars of *S. ganesa* and *S. insignis* appear to be indistinguishable from one another; the skull of the former, however, of which there is a magnificent specimen in the British Museum, is distinguished by its enormous tusks; while that of the latter, of which there are numerous specimens, by the peculiarly depressed form of the fronto-parietal region. Molars of either *S. insignis* or of the next species, if not of both, have been obtained from strata of probably pliocene age in Japan. The molars of the third species, *S. bombifrons*, are less complex than those of the preceding; its skull has very prominent frontals; remains of this species have been obtained from the pliocene (?) of China, and described under the name of *S. orientalis*. Of the fourth species, *S. clifti*, the skull is unknown, but the molars are still simpler, the intermediate ones bearing only six ridges each; remains of this species have also been obtained from Burma, Japan, and China, a tooth from the latter country having been named *S. sinensis*. Five species of mastodons are also known, three belonging to the tetra-, and two to the tri-lophodont subdivision of the genus. Of the former, *M. latidens* approaches nearest to the stegodons, and, as it has open valleys, and the intermediate molars occasionally carry five ridges, it affords such a complete transition between *S. clifti* and the other mastodons that it seems highly probable that the generic divisions of the elephants and mastodons should be swept away, and the whole of them included under one large genus. The skull of *M. latidens* is unknown; its remains have been obtained from the Irawádi valley, the Sub-Himalaya, Sind, and Perim Island. *M. perimensis* has the molars rather less regular than the last; there is a fine skull in the British Museum, and its remains have been found in the Panjáb and Perim Island. The third tetra-lophodont species, *M. sivalensis*, has the molars with an "alternate" arrangement of the ridges, and occasionally presenting a tendency to a pentalophodont formula; there is a fine skull in the British Museum, and remains of this species have been obtained only from the Sub-Himalaya. The skulls of the two trilophodont species are unknown, and all their remains, which are from the Panjáb, Sind, and Perim Island, are in the Indian Museum [1]. In the first, *M. falconeri*, the valleys of the molars are open, and the symphysis of the lower jaw is short, and sometimes provided with small cylindrical tusks. In the second, *M. pandionis*, the valleys of the molars are obstructed by outlying columns, and the symphysis of the lower jaw is produced into a long trough-like process, which may or may not be furnished with large compressed tusks. Of the genus *Dinotherium* three species are

[1] This is exclusive of the remains of *M. pandionis* from the pleistocene of Madras.

known: the largest of these, *D. indicum*, rivals in size the European *D. giganteum*; there are several specimens of the teeth and jaws in the Indian Museum, and also in the collection of the Bombay Branch of the Royal Asiatic Society; there is also a cervical vertebra, part of the mandible, and an upper molar in the British Museum; remains of this species have been obtained from the Panjáb and Perim Island. The second species, *D. pentapotamiæ*, is of smaller size, and has been obtained from the Panjáb, Kach, and Sind; numerous specimens of the teeth and jaws are exhibited in the Indian Museum. The last species, *D. sindiense*, is only known by two specimens of a part of the mandible, one from Sind and the other, lacking the crowns of the molars, from the Panjáb; both specimens are in the Indian Museum. The mandible in this species is subcylindrical in cross-section, and thereby approaches the mastodons.

Coming to the Ungulata, we find both the perisso-, and the artio-dactylate sections well represented, though the latter are by far the most numerous. Among the former, we have the rhinoceroses represented by three species of true *Rhinoceros*: the first of these was a unicorn form, apparently very closely allied to the living *R. javanicus* (*sondaicus*), which it resembles in the form of its molars and the mandible. Skulls and teeth of this species are contained both in the British and Indian Museums, and its remains have been obtained from the Sub-Himalaya and Sind. The second species, *R. palæindicus*, does not seem to come very near to any living form; this species was also unicorn, and the mandible had two pairs of incisors; the upper molars are intermediate in structure between those of the living Javan and Indian species. Most of the remains of this form are from the Sub-Himalaya, and are in the British Museum. The third species, *R. platyrhinus*, was of huge size, and furnished with two horns; its molars are of the complex type of *R. indicus*, and its mandible has no incisors like the mandibles of the living African species, and the extinct *R. pachygnathus* of Pikermi. Remains of this species have been obtained only from the Sub-Himalaya, and are nearly all in the British Museum, where there is a nearly complete skull. All the above species have high-crowned (hypsodont) molars. It is possible that certain remains from the Bhúgti hills, now in the hands of the writer, may indicate a new species of the genus, with a mandible resembling that part in the existing African species.

Imperfect molars of a species of *Rhinoceros* have been obtained from the pliocene of China, and described as *R. sinensis*. The hornless rhinoceroses are represented by the gigantic *Acerotherium perimense*[1], of which there are a fine skull and numerous teeth and jaws from the Panjáb, in the Indian Museum, and a magnificent palate and some specimens of the mandible, from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society; the British Museum also possesses a few specimens of teeth and jaws from Perim Island. The genus *Chalicotherium*, formerly classed among the artiodactylates, but now placed by many among the perissodactylates as a link between the rhinoceroses and the palæotheres, is represented by *C. sivalense*,—a species presenting a peculiarly aborted dentition, and hence referred by some to a distinct genus, under the name of *Nestoritherium*; it has been considered to be nearly allied to *Rhinoceros pachygnathus*. This species is of rare occurrence, but is known by an

[1] Syn. *Rhinoceros iravaticus* and *R. planidens*.

associated cranium and mandible, in the Museum of St. Andrew's University; by the upper molars of each maxilla and a mandible in the British Museum, and by a few lower molars in the Indian Museum. The latter specimens are from Sind, and the others from the Sub-Himalaya. Another species has been described from the pliocene of China. It seems doubtful whether the genus *Tapirus* occurs; the symphysis of a mandible from the Irawádi valley has indeed been referred to it, but the determination cannot be considered certain[1]. Fossil remains of the genus have, however, been obtained from the pliocene of China. The genus *Listriodon*, sometimes referred to the pigs, is represented by *L. pentapotamiæ* and *L. theobaldi*, the former being known by several molars, and the latter only by one molar of small size. All these teeth were obtained from the Panjáb, and are in the Indian Museum.

The horses are represented by the genera *Equus* and *Hippotherium* (*Hipparion*); of the former there are two species, *viz.*, *E. sivalensis*, apparently closely allied to the Tibetan kiang (*E. hemionus*), but retaining some ancestral characters, and *E. namadicus*, more nearly allied to the existing horse. Remains of these species have been obtained from the Sub-Himalaya, and one species of the genus from Perim, of which there are three molars in the Museum of Trinity College, Dublin. Of *Hippotherium* there are also two species, *viz.*, *H. antelopinum*, closely allied to the European *H. gracile*, and *H. theobaldi*, distinguished by its superior size, and the form of its upper milk-molars. The former has been obtained from the Sub-Himalaya and Perim Island, and there are numerous remains both in the British and Indian Museums. A fine skull from Perim has been recently sent on loan to the Indian Museum, and is the only known example. The latter has been obtained from the Panjáb, Burma, and Perim Island, and most of its remains are in the Indian Museum; it is not improbable that the range of this species extended to China, where molars belonging to some form of the genus have been obtained. Coming to the artiodactylates, we have among the bunodont pig-like animals two species of *Hippopotamus*, one of which, *H. sivalensis*, was of large size, and furnished with six incisors in either jaw; the other, *H. iravaticus*, is very imperfectly known, but seems to have been of small size. Remains of these species have been obtained from the Sub-Himalaya and the Irawádi valley. A large animal, *Tetraconodon magnum*, is known only by a broken mandible, from the Panjáb, in the Indian Museum, and of which there is a cast in the Museum of the Royal College of Surgeons, and by a figure of the upper dentition. The mandible is remarkable for the enormous size of the premolars, and indicates an animal allied to the European and American tertiary genus *Entelodon* (*Elotherium*), but distinguished by the greater relative size of the premolars, and the more regularly oblong form of the true molars. The true pigs (*Sus*) are represented by three species, the first of which, *S. giganteus*, is distinguished by its enormous size; there is a nearly complete skull, with the mandible attached, and with some of the limb-bones, of this fine species, as well as numerous other remains in the Indian Museum, and a large series of teeth and jaws in the British Museum, all of which have been obtained from the Panjáb and Sub-Himalaya. The second species, *S. hysudricus*, is smaller

[1] Remains of *Listriodon* have been described as *Tapirus*.

than the living wild-boar, and has been obtained from the Panjáb, Sub-Himalaya, Perim Island, and Sind. The last species, *S. punjabiensis*, is of very small dimensions, and is only known by two portions of the mandible from the Panjáb, now in the Indian Museum. *Hippohyus* is a genus peculiar to the Siwaliks, whose molars present a remarkable complex arrangement of the columns, recalling the pattern of the molars of the horse; it appears to have been represented by two species, both from the Sub-Himalaya, and one of which has been named *H. sivalensis*. *Sanitherium* is another genus peculiar to the Siwaliks, and is represented only by *S. schlagintweiti*, of which three fragments of the mandible are known, two being in Germany and the third in the Indian Museum; all three are from the Panjáb and Sub-Himalaya. The European miocene genus *Hyotherium* is represented by the molars of one species from Sind and Perim Island, which has been named *H. sindiense*; these teeth are in the Indian Museum. Of the selenodont pig-like animals, we have, among the group with five columns on the upper molars, two species of *Anthracotherium*, and two of *Hyopotamus*. Of the former, one species, *A. silistrense*, is of small size, and is known by three upper molars, and parts of the mandible; these specimens have been obtained from near Sylhet, the Panjáb, and Sind, and most of them are in the Indian Museum. The second species, *H. hyopotamoides*, is of large size, and is known by an upper molar in the Indian Museum, from the Bhúgti hills, to the north of Sind; some mandibles may also belong to this species. Of *Hyopotamus*, a small species, *H. palæindicus*, is known by several teeth and one lower jaw, from Sind, in the Indian Museum; the molars of this species differ somewhat from those of typical species. The second species, *H. giganteus*, is known by an upper molar, and by some specimens of the mandible from the Bhúgti hills, now in the Indian Museum[1]; the upper tooth much resembles that of *Anthracotherium hyopotamoides*, and with that species forms such a complete transition between the genera *Anthracotherium* and *Hyopotamus* that it seems highly probable that the two should be united. Among the forms characterised by having only four columns on the upper molars, there are four peculiar genera, each of which is known only by a single representative. The best known of these is *Merycopotamus*, represented by *M. dissimilis*, a genus allied to the hyopotamids by the structure of its teeth, and to the hippopotamus by the form of the mandible; this species has been obtained from the Sub-Himalaya and the Irawádi valley, and there are fine series of its remains in both the British and the Indian Museums. A second genus, *Hemimeryx*, is only certainly known by an upper molar of somewhat similar structure to the molars of the last genus; this specimen has been named *H. blanfordi*, and was obtained from Sind; it is now in the Indian Museum. Another upper molar in the same collection, also from Sind, has been named *Sivameryx sindiensis*, and indicates a smaller animal allied to the above. A maxilla with the upper molars, from the Garo hills, presented to the Geological Society, indicates another small animal of the same group, to which the name *Chœromeryx silistrensis* has been applied.

[1] Casts of the teeth of this species and of *A. hyopotamoides* will be found in the British Museum. The names of these, and of other selenodont Suina, are mentioned here for the first time, the memoir in which they are described being still in the press.

A single upper molar from Sind, in the Indian Museum, belongs to the American family *Oreodontidæ*, and has been provisionally referred to the genus *Agriochœrus*; it seems to be very close to the American *A. latifrons.*

Among the true ruminants we have the deer family represented by several imperfectly known species, at least one of which had large branching antlers. Of these, *Cervus triplidens* had a large accessory column to the molars, while in *C. simplicidens*, a species as large as *C. kashmirianus*, the accessory column is much smaller. In *C. sivalensis* the molars had very low crowns. The genus of the fourth species, *C. latidens*, is somewhat doubtful. Remains of these species have been obtained from the Panjáb and the Sub-Himalaya, and are numerously represented in the Indian Museum. The genus *Dorcatherium* is represented by the two species *D. majus* and *D. minus*, of which there are teeth in the Indian Museum, obtained from the Panjáb. A single upper molar in the Indian Museum, from the Panjáb, seems to belong to a genus related to *Palæomeryx*, for which the provisional name *Propalæomeryx sivalensis* has been proposed; it probably connects the true deer with the giraffe. The family *Camelopardalidæ*, which is taken to include both the giraffes and the sivatheres, is represented by several genera. In these we have a true giraffe, distinguished as *Camelopardalis sivalensis*, of which there are numerous teeth and a few bones in the British and Indian Museums, from the Sub-Himalaya, the Panjáb, and Perim Island. A species of *Helladotherium*, not distinguishable from *H. duvernoyi* of Europe, is represented by a single cranium in the British Museum. Of four genera peculiar to the Siwaliks, the first, *Vishnutherium*, is known by a part of the mandible from Burma, and probably by two upper molars, and some bones from the Panjáb, all of which are in the Indian Museum. It seems to come the nearest of the four to the giraffe, and has been named *V. iravaticum.* The second, *Hydaspitherium*, is known by two species, of which *H. megacephalum* is known by a skull and a large series of teeth and bones, all from the Panjáb, and now in the Indian Museum; it carried a massive common horn-base above the occiput, from which the horns took their origin. The second species, *H. grande*, was larger and is only known by the upper molars and the mandible, all from the Panjáb, and now in the Indian Museum. It is probable that a cervical vertebra from Beluchistan, in the collection of the Geological Society, belongs to one of the above species. The third genus, *Bramatherium*, is represented by *B. perimense*, of which the skull, teeth, mandible, and some of the limb-bones are known; this species carried a pair of horns above the occiput, and a large common horn-base on the frontals. Its remains have been obtained from Perim Island, and the one known skull is in the Museum of the Royal College of Surgeons, the upper molars in the British Museum, two fragments of the mandible in the Indian Museum, and another, with the last true molar, in the Museum of Trinity College, Dublin. The fourth genus is the well-known *Sivatherium* represented by the one species, *S. giganteum*, in which the skull was furnished with two pairs of horns. Remains of this species have been obtained only from the Sub-Himalaya eastward of the Panjáb, and the British Museum possesses a magnificent series of them. There has been much discussion as to the serial position of the foregoing forms, *Helladotherium*, with the giraffe, being classed by some with the stags, while *Sivatherium* and the two preceding genera are classed with the antelopes. The resemblance of the teeth of all these animals is, however, so close that it seems preferable to class them all together in one large family, connecting the deer with the antelopes.

Of the antelopes, the best known is the so-called *Antilope palæindica*, which seems to have been closely allied to the South African genus *Damalis* (Bonte-bok, and Sassaby), and should probably be termed *D. palæindica;* there are two skulls in the Indian and one in the British Museum, all from the Sub-Himalaya. A skull from the same locality, in the Indian Museum, indicates a second species of antelope closely allied to the living Indian *A. cervicapra*, which has been named *A. sivalensis*. A third species, *A. acuticornis*, is indicated by numerous horn-cores from the Panjáb, in the Indian Museum, and was probably a kind of gazelle. A fourth species, *A. patulicornis*, has been named from a pair of horn-cores in the same collection. A species of *Portax* is indicated by numerous teeth and a fore-limb, in the Indian Museum; while other molars in the same collection not improbably belong to the genus *Palæoryx*, of the Pikermi beds. The oxen are represented by numerous species, three of which are here referred to one genus under the name of *Hemibos*, but have also been referred to two genera under the names of *Probubalus* and *Amphibos;* the group is closely allied to, if not identical with, the living Celebes genus *Anoa*, which has been referred to it under the name of *Probubalus celebensis*. The first species of *Hemibos* is named *H. occipitalis*, and varies considerably in the form of its horn-cores, which are sometimes nearly straight and triangular in section, and at others curved and pyriform in section; another variety is hornless. There are fine series of the skulls of this species, both in the British and the Indian Museums, all from the Sub-Himalaya. The second species, *H. antilopinus*, is also known by several skulls from the same districts. The third species *H.* (*Amphibos*) *acuticornis*, is a long-horned form, and is also represented by numerous skulls, from the Sub-Himalaya, in the British and Indian Museums. *Leptobos falconeri* is a fourth form of ox, which was in some cases hornless, of which there are several crania in the British Museum. The genus *Bubalus* is represented by two species; the first of these, *B. platyceros* (*sivalensis*), is known by one cranium in the British and another in the Indian Museum, both from the Sub-Himalaya; the horns were stout and concave superiorly. The second species is *B. palæindicus*, which occurs also in the pleistocene, if, indeed, the topmost beds of the Siwaliks in which it occurs should not be referred to that period; this species is evidently only a race of the living *B arni*, and is very probably the same as *B. pallasi* from the pleistocene of Danzig. One skull from the Sub-Himalaya, in the Indian Museum, belongs to a species of *Bubalus*, and has been named *B. sivalensis;* it is the earliest form of the genus, and seems to have been allied to the fossil European *B. priscus*. Of the true oxen (*Bos*), three species have been named, *viz.*, *B. acutifrons*, remarkable for its enormous horns and angulated frontals; *B. planifrons*, with shorter horns and flattened frontals, and closely allied to the European *B. primigenius;* and *B. platyrhinus*, only known by the lower half of a skull of which the generic affinities are doubtful. The latter specimen, as well as a skull of each of the preceding species, are in the Indian Museum, and came from the Sub-Himalaya. Species of *Bos* or allied genera are indicated from Perim Island by molars in the Museum of Trinity College, Dublin.

A remarkable hornless skull, of comparatively large size, from the Sub-Himalaya, in the collection of the British Museum, has been described under the name of *Bucapra daviesi;* this skull comes nearest to the skulls of the goats, while the molars are of a bovine type, and, if found separately, would certainly have been referred to some form of oxen. There is evidence of three species of true goats, the first of which, *Capra sivalensis,* is known by two skulls in the British Museum, from the Sub-Himalaya, and is considered to be allied to the jharal of the Nilgherries (*Hemitragus jemlaicus*), and not improbably belongs to the same genus. The second species, *C. perimensis,* is known by a portion of a skull in the Indian Museum from Perim Island, and was probably allied to the living markhoor (*C. falconeri*) of the Himalaya, though the horn-cores do not show a spiral twist. The third species is unnamed, since its horn-cores, of which the Indian Museum possesses numerous specimens from the Panjáb, are so like those of the markhoor that it is difficult to point out characters of specific distinction with the materials available; it is possible that the horns may belong to older individuals of *C. perimensis.* It has been stated that a cranium from the Sub-Himalaya, which is not now forthcoming, belongs to the living Himalayan ibex (*C. sibirica*), butthis determination requires confirmation, although it is highly likely that the specimen may have belonged to an allied species. Another cranium, also lost, has been referred to the genus *Ovis.*

A species of chevrotain has been determined from the evidence of a single upper molar, from the Panjáb, in the Indian Museum, under the name of *Tragulus sivalensis.*

The camels are known by *Camelus sivalensis,* which presents a peculiarity in the structure of its lower molars, connecting it with the llamas (*Auchenia*) of America. Remains of this species have been obtained from the higher beds of the Sub-Himalayan Siwaliks, and are well represented in both the British and Indian Museums.

The remaining orders of the mammalia are only represented by a few species of rodents, and by one edentate. Of the former, a species of rat (*Mus*) is indicated by some incisors from the Sub-Himalaya. A species of bambú-rat (*Rhizomys sivalensis*[1]) has been determined on the evidence of three specimens of the mandible from the Panjáb now in the Indian Museum. A porcupine (*Hystrix sivalensis*) is known by a part of the cranium and the mandible, the former being in the British and the latter in the Indian Museum; one is from the Sub-Himalaya and the other from the Panjáb.

The edentates are known by one species of pangolin, *Manis sindiensis,* named on the evidence of a solitary phalangeal bone from Sind, now in the Indian Museum. The species must have been about four times the size of the living Indian *M. pentadactylus.*

Pleistocene.—Coming to the pleistocene, we find that its mammals are even less well known than those of the pliocene. As the pleistocene ossiferous strata are distributed in patches, very frequently in the valleys of the great rivers, the

[1] Probably the same as *Typhlodon* of Falconer.

remains from the more important of these areas must be treated of separately. The most important areas are parts of Madras and the Deccan; the valleys of the Jamna, Narbada, Pemganga, Krishna (Kistna), and Godávari, with their numerous tributaries, and the plains of Húndes in Tibet. It is also not improbable, as already mentioned, that the topmost strata of the Sub-Himalayan Siwaliks should really be referred to the pleistocene. In many instances, as in the delta of the Ganges, it is difficult, if not impossible, to draw any satisfactory line of distinction between the pleistocene and the prehistoric deposits. The presence in any stratum of the remains of *Hippopotamus*, or other genus not now found living in India, is considered as fair evidence for assigning such deposit to the pleistocene.

From the laterite of Madras palæolithic implements and a human platycnemic tibia have been obtained, and are assigned to the pleistocene.

From the alluvium of the Krishna valley, in the Deccan, a part of the skull and the mandible of a rhinoceros have been obtained and described under the name of *Rhinoceros deccanensis*. This species seems to be more nearly allied to the living African and the pliocene European species than to any living Indian form. Remains of an ox, not improbably *Bos namadicus*, have also been obtained from the same deposits, and, with the last-mentioned specimens, are in the Indian Museum. Certain molars of the pliocene *Mastodon pandionis* from the Deccan, and now in the British Museum, were not improbably derived from the same deposits in the upper part of the Krishna basin.

From the ossiferous gravels of the Narbada palæolithic implements of a rude form have been found associated with mammalian bones. The carnivora are represented by a small species of bear (*Ursus namadicus*), of which there are a maxilla and a tibia in the British, and a canine in the Indian Museum; and a large species of *Felis* is indicated by the distal extremity of a femur in the former collection. Of the Proboscidia, there is *Euelephas namadicus*, characterised by its prominent frontal ridge, and whose molars very closely resemble those of the European *E. antiquus*, from which resemblance it has been thought that the two forms may belong to the same species. The Indian species has also been obtained from Japan. There is one fine skull in the British Museum, and three skulls in the Indian Museum. *Stegodon* is represented by *S. ganesa*, of which there is a fine tusk in the Indian Museum, and very probably by *S. insignis*. The perissodactyles are represented by *Rhinoceros indicus*, of which the Indian Museum has two molars, and by a little-known extinct form to which the name *R. namadicus* has been applied; there is a scapula of this species in the last-named collection. There is also a species of horse, *Equus namadicus*, which seems to be a survivor from the Siwaliks. Among the Artiodactyla two species of hippopotamus were originally described under the names of *Hippopotamus namadicus* and *H. palæindicus*; the former having six, and the latter four, incisors. Specimens in the Indian Museum seem, however, to show that there is a transition in these respects between these two so-called species, and all the remains have accordingly been referred to *H. palæindicus*, which was hexaprotodont in some individuals, and tetraprotodont in others. The pigs seem to have been represented by *Sus giganteus*, another survivor from the Siwaliks. Remains of a deer apparently very close to, if not identical with, the living Indian *Cervus duvaucelli*, have been obtained, and there is some evidence of a second species. Three species of oxen have been described, *viz.*, *Bos namadicus*, a species showing some affinity to the Asiatic genus *Bibos*, of which there is a magnificent skull in the Indian Museum; *Bubalus palæindicus*, also occurring in the topmost Siwaliks, and the ancestor of *B. arni*; and *Leptobos frazeri*, which was sometimes hornless, and is represented by some fine skulls in the British Museum. A species of nilghai, of which there are two broken crania in the same collection, has been named *Portax namadicus*; it is distinguished from the living species, among other characters, by the horns being placed nearer to the orbits. The rodents are only known by some incisors in the Indian Museum, probably belonging to a species of *Mus*.

From the pleistocene of the Jumna valley only four mammals have been specifically determined with any certainty, *viz.*, *Euelephas namadicus*, *Bubalus palæindicus*, *Hippopotamus palæindicus*, and the living *Antilope cervicapra*; the latter being known by a single horn-core in the Indian Museum. In addition to these, remains of a species of *Semnopithecus*, *Sus*, *Portax*, *Equus*, *Mus*, and of a *Rhinoceros* furnished with lower incisors, have also been obtained. A tiger, as large as the existing species, is indicated by a scapho-lunar bone in the Indian Museum; this species was very probably the same as the Narbada form, and may have been *Felis tigris*.

The pleistocene of the Pemganga valley has yielded remains of *Bos namadicus*, a *Portax*, and *Hippopotamus palæindicus*.

The remains from the Godávari deposits have not been satisfactorily determined.

The horizontal lacustrine strata of Húndes in Tibet formerly classed as Siwalik, but which are more probably of pleistocene age, have yielded a small number of mammalian remains. Among these is a tooth referred to a species of *Hyæna*. Bones belonging to some form of horse have also been obtained, among which a cannon-bone in the collection of the Geological Society belongs to a species of *Hippotherium*, a genus elsewhere unknown in the pleistocene. Several of the limb-bones and the fragment of an upper molar of a rhinoceros are also known, but they are too imperfect for specific determination. The other known fossils belong to ruminants, the best preserved of which is the greater portion of the skull of an antelope, provisionally referred to the living Tibetan genus *Pantholops*, under the name of *P. hundesiensis*; this specimen cannot now be found, but is figured in Royle's "Illustrations of the Botany of the Himalaya Mountains." There is also a skull said to belong to some genus of bovine animal; another belonging to a goat resembling the markhoor (*Capra falconeri*); and a palate, in the collection of the Geological Society, doubtfully referred to a sheep (*Ovis*).

It may be added that mammalian remains are stated to have been obtained from a cave in the Karnúl district of Madras; these remains have, however, never been described, and cannot now be found.

Prehistoric.—The prehistoric deposits, as already said, have in many cases not yet been satisfactorily separated from the pleistocene, and the very local occurrence of vertebrate remains in the former renders this point of doubt one not likely to be soon cleared up. Any old alluvial deposit in which bones of only living mammals occur is here provisionally referred to the prehistoric.

Human remains and neolithic implements have been obtained in the alluvium of the plains in many localities, and frequently at considerable distances below the surface; the former are generally very imperfectly preserved and have never been carefully examined. Polished celts are extremely abundant in many places, and particularly in Burma and the Banda district of the North-West Provinces. The prevailing types are elongated forms with oval section, wedges, and the "shouldered" form. Among the mammals specimens of the teeth and jaws of *Macacus rhesus* from the alluvium and turbary of Goalpára, in Assam, and from Madras are exhibited in the Indian Museum, those from the former district being in a highly mineralised condition. Molars of the Indian elephant occur at considerable depths in the alluvium of the plains and of Burma. A last upper molar of *Rhinoceros indicus*, in the Indian Museum, was obtained from the turbary of Madras, and indicates the former extensive range of this species. It may be observed, in passing, that the range of the other species of *Rhinoceros* was probably much more extensive than at present, even in the historic period, because it has been inferred that the species killed by Akbar on the banks of the Indus was *R. javanicus* (*Sondaicus*), this inference being founded on the improbability of its being possible to kill *R. indicus* by means of arrows, with which Akbar's animals were destroyed. *Sus indicus* has also been obtained from the turbaries of Madras and Calcutta. Antlers, horn-cores, and teeth of undetermined species of *Bos* and *Cervus* have been obtained from the alluvium of various districts in the plains, and from raised beaches in Kattiawár; some of the latter deposits being probably in part of pleistocene age.

General.—Of the mammalia as a whole it may be observed that those of the pliocene are characterised by the great number of forms belonging to the orders which include animals of large corporeal bulk. Another noticeable point is the admixture of genera characteristic of modern Africa (*Hippopotamus*, *Camelopardalis*) and other parts of the old world (*Bos*, *Capra*, *Ursus*, *Equus*, etc.); of oligocene, miocene, and pliocene Europe (*Dinotherium*, *Anthracotherium*, *Hippotherium*, etc.) with those now peculiar to Asia (*Euelephas*, *Rhinoceros* [in its restricted sense] etc.). Among orders which have now diminished extensively in numbers in India, the Proboscidia stands pre-eminent, its fourteen Siwalik representatives having now dwindled to one. The perrissodactylate Ungulata have also diminished considerably, the modern forms inhabiting India and the adjacent countries being five and the extinct eleven or twelve. The artiodactylate modification has perhaps suffered a still more serious diminution, especially among the pig-like animals, in which the whole of the selenodont group like *Merycopotamus* and *Hyopotamus* has completely disappeared, while their congener, the hippopotamus, is now confined to Africa, and the Indian wild-boar and the diminutive terai hog (*Porcula*) are the sole representatives now remaining. The ruminants have lost their larger representatives, either entirely (*Sivatherium*) or by transference to Africa (*Camelopardalis*), and some of their smaller forms are considered to be allied to South Indian (*Hemitragus*) or South African form (*Damalis*), while others have always been exclusively Indian, (*Bortae*). The diminution in numbers of the ruminants cannot be clearly indicated owing to the numbers of small forms now existing, when analogues cannot be determined in the Siwaliks. Similarly, owing to the poverty of the remains of the other orders, and of the almost total absence of the micro-mammalia, comparisons cannot be instituted between the numbers of the recent and fossil species, but enough has been indicated to show that modern India has only the impoverished remains of a once extensive fauna of mighty forms. Regarding the range in space of the Siwalik fauna, it is probable that this was once very extensive, as we find some of the species ranging as far as China and Japan, and it has even been suggested that one species (*Hyaenarctos sivalensis*) occurs in the pliocene of England. Representatives of some of the other common Siwalik or Indian genera, although considered to be specifically distinct, have also been obtained from China (*e.g.*, *Chalicotherium*, *Rhinoceros*, *Tapirus*, and *Hyaena*). It may also be observed that the mammals from Sind belong mainly to European oligocene and miocene genera, while those from the Panjáb show a mixture of miocene, pliocene, and existing genera; the two latter prevailing more extensively, as we proceed eastward along the Sub-Himalaya. The high degree of evolution or specialisation of many of the genera is a marked feature, and one strongly confirmative of their pliocene age. Thus, it may be noticed that the rhinoceroses had high-crowned molars, and that in one form the incisors were absent and two horns present; while some of the horses had reduced their digits to one on each limb. The pigs had well-developed tusks, the deer large branching antlers, the oxen wide-spreading horns, and the cats (*Machairodus*) huge trenchant fangs.

In the pleistocene the majority of the larger forms had disappeared, though a few of the extinct genera and species still lingered on. Many of the existing species were already in existence, or were represented by closely allied forms. Palæontological history is, however, still silent as to the origin of some of the larger existing mammals, like the Indian elephant. Some new forms (*e.g.*, *Bos namadicus*), which cannot be directly traced back to pliocene ancestors, seem to have appeared and to have died out again before the prehistoric.

In the latter period all the mammals seem to belong to existing species, although the range in space of some of them was more extensive than at present.

SYSTEMATIC CHRONOLOGICAL LIST OF SPECIES.

A.—ANTHROPOZOIC.

a.—PREHISTORIC.

MAMMALIA	PRIMATES	Homo (? sapiens, Lin.).
		Macacus rhesus (F. Cuv.).
	PROBOSCIDIA	Euelephas indicus, Linné.
	UNGULATA	Rhinoceros indicus, Cuvier.
		Sus indicus, Gray.
		Cervus, sp.
		Bos, sp.
REPTILIA	CHELONIA	Gen. nov. det.

b.—Pleistocene.

MAMMALIA	Primates . . .	Homo, sp.
		Semnopithecus, sp.
		Ursus namadicus, F. & C.
		Hyæna, sp.
		Felis (? tigris, Lin.).
	Proboscidia . .	Euelephas namadicus, F. & C.
		Stegodon ganesa, F. & C.
		(?) ——— insignis, F. & C.
		Mastodon pandionis, Falc.
	Ungulata . .	Rhinoceros deccanensis, Foote.
		——— indicus, Cuv.
		——— namadicus, F. & C.
		——— sp.
		Equus namadicus, F. & C.
		Hippotherium, sp.
		Sus giganteus, F. & C.
		Cervus (? duvaucelli, Cuv.).
		Bubalus palæindicus, F. & C.
		Bos namadicus, F. & C.
		Leptobos fraseri, Rüt.
		Portax namadicus, Rüt.
		Antilope cervicapra, Pallas.
		Pantholops (?) hundesiensis, Lyd.
		Capra, sp,
		Ovis, (?) sp.
	Rodentia . .	Mus, sp.
REPTILIA	Crocodilia . .	Crocodilus, (?) sp.
	Chelonia . .	Pangshura tectum (Bell)
		Batagur (? dhongoka, Blyth).
		Trionyx (? gangeticus, Cuv.).

B.—THERIOZOIC.

a.—Pliocene [1].

MAMMALIA .	Primates . . .	Palæopithecus sivalensis, Lyd.
		Macacus sivalensis, Lyd.
		——— sp.
		Semnopithecus (?) sub-himalayanus, Myr.
		——— sp.
	Carnivora . .	Felis cristata, F. & C.
		——— sp.
		Machairodus sivalensis, F. & C.
		Pseudælurus sivalensis, F. & C.
		Ictitherium sivalense, Lyd.
		Viverra bakeri, Bose.
		Hyæna sivalensis, F. & C.
		Canis curvipalatus, Bose.
		——— cautleyi, Bose.
		† Amphicyon palæindicus, Lyd.
		Ursus, sp.

[1] The forms of the earlier pliocene are marked by a cross (†).

MAMMALIA .	. CARNIVORA . .	. Hyænarctos sivalensis, F. & C.
		——— palæindicus, Lyd.
		Mellivora sivalensis, F. & C.
		Meles, sp.
		Lutra palæindica, F. & C.
		—— sp.
		Enhydriodon sivalensis, F. & C.
	PROBOSCIDIA .	. Euelephas hysudricus, F. & C.
		Loxodon planifrons, F. & C.
		Stegodon ganesa, F. & C.
		——— insignis, F. & C.
		——— bombifrons, F. & C.
		——— cliftii, F. & C.
		† Mastodon latidens, Clift.
		——— sivalensis, F. & C.
		† ——— perimensis, F. & C.
		† ——— pandionis, Falc.
		† ——— falconeri, Lyd.
		† Dinotherium sindiense, Lyd.
		† ——— pentapotamiæ, Falc.
		——— indicum, Falc.
	UNGULATA	. † Chalicotherium sivalense, F. & C.
		Rhinoceros palæindicus, F. & C.
		——— platyrhinus, F. & C.
		† ——— sivalensis, F. & C.
		† Acerotherium perimense, F. & C.
		Listriodon pentapotamiæ, Falc.
		——— theobaldi, Lyd.
		(?) Tapirus sp.
		Equus sivalensis, F. & C.
		—— namadicus, F. & C.
		Hippotherium antilopinum, F. & C.
		——— theobaldi, Lyd.
		Hippopotamus iravaticus, F. & C.
		——— sivalensis, F. & C.
		Tetraconodon magnum, Falc.
		Sus giganteus, F. & C.
		† — hysudricus, F & C.
		— punjabiensis, Lyd.
		Hippohyus sivalensis, F. & C.
		——— sp.
		Sanitherium schlagintweiti, Myr.
		† Hyotherium sindiense, Lyd.
		† Anthracotherium silistrense (Pent).
		† ——— hyopotamoides, Lyd.
		† Hyopotamus palæindicus, Lyd.
		† ——— giganteus, Lyd.
		Merycopotamus dissimilis, F. & C.
		Chœromeryx silistrensis (Pent).
		† Hemimeryx blanfordi, Lyd.
		† Sivameryx sindiensis, Lyd.
		† Agriochœrus, (?) sp.
		Cervus triplidens, Lyd.
		—— sivalensis, Lyd.

MAMMALIA .	. UNGULATA .	. Cervus simplicidens, Lyd.
		—— (?) latidens, Lyd.
		Dorcatherium majus, Lyd.
		—— minus, Lyd.
		Propalæomeryx sivalensis, Lyd.
		Camelopardalis sivalensis, F. & C.
		Helladotherium duvernoyi, Wag.
		Vishnutherium iravaticum, Lyd.
		Hydaspitherium grande, Lyd.
		—— megacephalum, Lyd.
		Sivatherium giganteum, F. & C.
		Antilope (? Damalis) palæindica, F. & C.
		—— patulicornis, Lyd.
		—— (? Gazella) porrecticornis, Lyd.
		—— sivalensis, Lyd.
		Palæoryx, (?) sp.
		Portax, sp.
		Hemibos occipitalis, Falc.
		—— acuticornis, Falc.
		—— antilopinus, Falc.
		Leptobos falconeri, Rut.
		Bubalus platyceros, Lyd.
		—— palæindicus, F. & C.
		Bison sivalensis, Falc.
		Bos acutifrons, Lyd.
		—— planifrons, Lyd.
		—— (?) platyrhinus, Lyd.
		Bucapra daviesi, Rut.
		Capra (? Hemitragus) sivalensis, Lyd.
		—— perimensis, Lyd.
		—— sp.
		Ovis, (?) sp.
		Tragulus sivalensis, Lyd.
		Camelus sivalensis, F. & C.
	RODENTIA .	. Mus, sp.
		Rhizomys sivalensis, Lyd.
		Hystrix sivalensis, Lyd.
	EDENTATA .	. † Manis sindiensis, Lyd.
AVES . .	. CARINATÆ .	. Graculus, (?) sp.
		Pelecanus cautleyi, Dav.
		—— (?) sivalensis, Dav.
		Megaloscelornis sivalensis, Lyd.
		† —— (?) sp
		Argala falconeri, M. Ed.
	RATITÆ .	. Struthio asiaticus, M. Ed.
		Dromæus sivalensis, Lyd.
		Gen. *non det.*
REPTILIA .	. CROCODILIA .	. Crocodilus, palustris, Less.
		Gharialis gangeticus, Gmel.
		—— leptodus, F. & C.
		† —— crassidens, F. & C.
	LACERTILIA .	. Varanus sivalensis, Falc.
	OPHIDIA .	. † Python (? molurus, Lin.).
	CHELONIA .	. Colossochelys atlas, F. & C.

REPTILIA	CHELONIA	Testudo (?) 5, sp.
		Bellia sivalensis, Theo.
		—— sp.
		Damonia hamiltoni, Gray.
		Emys, sp.
		Cantleya annuliger, Theo.
		Pangshura tectum (Bell).
		† Batagur, sp.
		† Trionyx, sp.
		Emyda vittata, Pet
PISCES	ELASMOBRANCHII	Carcharias, sp.
		Lamna, sp.
	TELEOSTEI	Bagarius yarrelli, Syk.
		Arius, sp.
		Gen. *non. det.*

b.—MIOCENE.

MAMMALIA	UNGULATA	Rhinoceros sivalensis v. gajensis, Lyd.

c.—EOCENE

MAMMALIA	UNGULATA	(?) Palæotherium, sp.
		Artiodactyle, gen. *non det.*
REPTILIA	CROCODILIA	Gen. *non det.*
	CHELONIA	Hydraspis leithi, Carter.
AMPHIBIA	ANOURA	Oxyglossus pusillus, Owen
		———— (?) sp.
PISCES	ELASMOBRANCHII	Myliobatis, sp.
	TELEOSTEI	Diodon foleyi, Lyd.
		Capitodus indicus, Lyd.
		Gen. *non det.*

C.—SAUROZOIC.

a.—CRETACEOUS.

REPTILIA	DINOSAURIA	Megalosaurus, sp.
		Titanosaurus blanfordi, Lyd.
		———— indicus, Lyd.
		Gen. *non det.*
	CROCODILIA	Gen. *non det.*
	CHELONIA	Gen. *non det.*
	ICHTHYOSAURIA	Ichthyosaurus indicus, Lyd.
PISCES	ELASMOBRANCHII	Corax incisus, Eg.
		——— pristodontus, Ag.
		Enchodus serratus, Eg.
		Lamna complanata, Eg.
		——— sigmoides, Eg.
		Odontaspis constrictus, Eg.
		———— oxypeion, Eg.
		Otodus basalis, Eg.
		——— divergens, Eg.
		——— marginatus, Eg.
		——— minutus, Eg.
		——— nanus, Eg.
		——— semiplicatus, Eg.

PISCES	ELASMOBRANCHII	Oxyrhina triangularis, Ag.
		——— sp.
		Ptychodus latissimus, Ag.
		Sphyrænodus, (?), sp.
	GANOIDEI	Pycnodus (?), sp.

b.—JURA-TRIAS.

REPTILIA	DINOSAURIA	Ankistrodon indicus, Hux.
	CROCODILIA	Gen. *non det.* (Chari gp.).
		Parasuchus hislopi, Hux. Ms.
		Gen. *non det.* (Rewah.).
	LACERTILIA	Hyperodapedon huxleyi, Lyd.
	DICYNODONTIA	Dicynodon orientalis, Hux.
		——— sp.
	PLESIOSAURIA	Plesiosaurus indicus, Lyd.
AMPHIBIA	LABYRINTHODONTIA	Brachyops laticeps, Owen.
		Gonioglyptus longirostris, Hux.
		——— huxleyi, Lyd.
		Glyptognathus fragilis, Lyd.
		Pachygonia incurvata, Hux.
		Archegosaurus, (?), sp.
		Gen. *non det.*
PISCES	GANOIDEI	Ceratodus[1] hislopianus, Old.
		——— hunterianus, Old.
		——— virapa, Old.
		Dapedius egertoni, Syk.
		Lepidotus breviceps, Eg.
		——— calcaratus, Eg.
		——— deccanensis, Eg.
		——— longiceps, Eg.
		——— pachylepis, Eg
		Tetragonolepis analis, Eg
		——— oldhami, Eg.
		——— rugosus, Eg.
		Gen. non det.

D.—ICHTHYOZOIC.

CARBONIFEROUS.

PISCES	GANOIDEI	Sigmodus dubius, Waag.
		Pœcilodus paradoxus, Waag.
		Psephodus indicus, Waag.
		Saurichthys indicus (?), De Kon.
	ELASMOBRANCHII	Helodopsis elongata, Waag.
		——— abbreviata, Waag.
		Psammodus, sp.
		Petalorhynchus indicus, Waag.
		Xystracanthus gracilis, Waag.
		——— major, Waag.
		——— giganteus, Waag.
		Thaumatacanthus blanfordi, Waag.
		Acrodus flemingi, De Kon.
		——— sp.

[1] Following Professor Miall ("Monograph of the Sirenoid and Crossopterygian Ganoids," Palæontographical Society, 1878), the order Dipnoi is merged with the Ganoidei.

ALPHABETICAL AND SYNOPTICAL LIST OF SPECIES, ARRANGED IN CLASSES[1].

CLASS I.—PISCES.

Acrodus flemingi, De Kon.	Salt-range	Carboniferous.
—— sp.	"	"
Arius	Panjáb and Sind	Pliocene.
‡ Bagarius yarrelli, Sykes *Pimelodus bagarius*, Syk.	Sub-Himalaya	Higher pliocene.
Capitodus indicus, Lyd.	Panjáb	Eocene.
Carcharias, sp.	Burma	Higher pliocene.
Ceratodus hislopianus, Old.	Maleri	Trias-jura.
—— hunterianus, Old.	"	"
—— virapa, Old.	"	"
Corax incisus, Eg.	Trichinopoli	Cretaceous.
—— pristodontus, Ag.	Trichinopoli and Europe	"
Dapedius egertoni, Syk.	Kota	Trias-jura.
Diodon foleyi, Lyd.	Rámri and Andamans	Eocene.
Enchodus serratus, Eg.	Trichinopoli	Cretaceous.
Helodopsis abbreviata, Waag.	Salt-range	Carboniferous.
—— elongata, Waag.	"	"
Lamna complanata, Eg.	Trichinopoli	Cretaceous
—— sigmoides, Eg.	"	"
—— sp.	Burma	Higher pliocene.
Lepidotus breviceps, Eg.	Kota	Trias-jura.
—— calcaratus, Eg.	"	"
—— deccanensis, Eg.	"	"
—— longiceps, Eg.	"	"
—— pachylepis, Eg.	"	"
Myliobatis, sp.	Panjáb	Eocene.
Odontaspis constrictus, Eg.	Trichinopoli	Cretaceous.
—— oxypeion, Eg.	"	"
Otodus basalis, Eg.	"	"
—— divergens, Eg.	"	"
—— marginatus, Eg.	"	"
—— minutus, Eg.	"	"
—— nanus, Eg.	"	"
—— semiplicatus, Eg.	"	"
Oxyrhina triangularis, Eg.	"	"
—— sp.	"	"
Petalorhynchus indicus, Waag.	Salt-range	Carboniferous.
Pœcilodus paradoxus, Waag.	"	"
Psammodus, sp.	"	"
Psephodus indicus, Waag.	"	"
Ptychodus latissimus, Ag.	Trichinopoli and Europe	Cretaceous.
Pycnodus, (?) sp.	Trichinopoli	"
Saurichthys indicus (?), De Kon.	Salt-range	Carboniferous.
Sigmodus dubius, Waag.	"	"
Sphyrænodus, (?) sp.	Lameta gp.	Cretaceous.

[1] Synonyms (of which only the more important are given) are in italics; living species are indicated by a double cross (‡), and fossil genera peculiar to India or Burma by an asterisk (*).

Tetragonolepis analis, Eg.	Kota	Trias-jura.
——— oldhami, Eg.	„	„
——— rugosus, Eg.	„	„
Thaumatacanthus blanfordi, Waag.	Salt-range	Carboniferous.
Xystracanthus giganteus, Waag.	„	„
——— gracilis, Waag.	„	„
——— major, Waag.	„	„

CLASS II.—AMPHIBIA.

Archegosaurus, (?) sp.	Bijori gp.	Trias-jura.
* Brachyops laticeps, Owen.	Mangli	„
* Glyptognathus fragilis, Lyd.	Panchet gp.	„
* Gonioglyptus huxleyi, Lyd.	„	„
* ——— longirostris, Hux.	„	„
Oxyglossus pusillus, Owen (*Rana pusilla*, Owen).	Bombay	Eocene.
——— (?) sp.	„	„
* Pachygonia incurvata, Hux.	Panchet gp.	Trias-jura.

CLASS III.—REPTILIA.

* Ankistrodon indicus, Hux.	Panchet gp.	Trias-jura.
‡ Batagur (? dhonkoka, Blyth)	Narbada	Pleistocene.
Bellia sivalensis, Theo.	Panjáb	Higher pliocene.
——— sp.	„	„
* Cautleya annuliger, Theo.	„	„
* Colossochelys atlas, F. & C.	Sub-Himalaya and Burma	„
‡ Crocodilus palustris, Less. (*C. bombifrons*, Gray.)	Sub-Himalaya and (?) Narbada.	Higher pliocene and (?) pleistocene.
‡ Damonia hamiltoni, Gray (*Emys hamiltonoides*, Falc.) (*Damonia hamiltonoides*, Falc.)	Sub-Himalaya	Higher pliocene.
Dicynodon orientalis, Hux. (*Ptychognathus orientalis*, Hux.)	Panchet gp.	Trias-jura.
‡ Emyda vittata, Peters (*E. ceylonensis*, Gray.)	Sub-Himalaya, &c.	Higher pliocene.
Emys, sp.	„	„
‡ Gharialis crassidens, F. & C. (*Crocodilus crassidens*, F. & C.) (*Leptorhynchus crassidens*, F. & C.)	Sub-Himalaya and Sind	Pliocene.
‡ ——— gangeticus, Gmel. (*Leptorhynchus gangeticus*, Gmel.)	Sub-Himalaya, Burma, Sind, and Perim.	„
——— leptodus, F. & C. (*Leptorhynchus leptodus*, F. & C.)	Sub-Himalaya, Burma, Sind, and Perim	„
Hydraspis leithi, Carter (*Testudo leithi*, Carter.)	Bombay	Eocene.
Hyperodapedon huxleyi, Lyd,	Maleri and South Rewá	Trias-jura.
Ichthyosaurus indicus, Lyd.	Trichinopoli	Cretaceous.
Megalosaurus, sp.	Trichinopoli and Lameta gp.	„
‡ Pangshura tectum, Bell (*Emys tectum*, Bell).	Sub-Himalaya and Narbada.	Higher pliocene and pleistocene.

* Parasuchus hislopi, Hux.	Maleri	Trias-jura.
——— (?), sp.	Denwa gp.	„
Plesiosaurus indicus, Lyd.	Umia gp.	Jura.
‡ Python (? molurus, Lin.)	Panjáb and Sind	Pliocene.
Testudo, *sp. var.*	Sub-Himalaya	Higher pliocene.
* Titanosaurus blanfordi, Lyd.	Lameta gp.	Cretaceous.
——— indicus, Lyd.	„	„
‡ Trionyx (? gangeticus, Cuv.)	Narbada	Pleistocene.
——— sp.	Sub-Himalaya	Higher pliocene.
Varanus sivalensis, F. & C.	„	„

CLASS IV.—AVES.

Argala falconeri, M. Ed. (*Leptoptilus falconeri* [M. Ed.])	Sub-Himalaya	Higher pliocene.
Dromaeus sivalensis, Lyd.	„	„
Graculus (?), sp.	„	„
Megaloscelornis sivalensis, Lyd.	„	„
Pelecanus cautleyi, Dav.	„	„
——— (?) sivalensis, Dav.	„	„
Struthio asiaticus, M. Ed. (*S. palaeindicus*, Falc.)	„	„

CLASS V.—MAMMALIA.

Acerotherium perimense, F. & C. (*Rhinoceros iravaticus*, Lyd.) (——— *perimensis*, F. & C.) (——— *planidens*, Lyd.)	Panjáb, Burma, Perim, and Sind	Pliocene.
Agriochoerus (?)	Sind	Earlier pliocene.
Amphicyon palaeindicus, Lyd.	Panjáb and Sind	Pliocene.
Anthracotherium hyopotamoides, Lyd.	Bhúgti hills	Earlier pliocene.
——— silistrense, Pent. (*Chaeromeryx silistrensis*, Pent.) (*Rhagatherium ? sindiense*, Lyd.) (*A. punjabiense*, Lyd.)	Sind, Gáro hills, and Panjáb	„
‡ Antilope cervicapra, Pallas (*A. bezoartica*, Ald.)	Jamna	Pleistocene.
——— palaeindica, F. & C. (*Damalis* (?) *palaeindica*, F. & C.)	Sub-Himalaya	Higher pliocene.
——— patulicornis, Lyd.	„	„
——— porrecticornis, Lyd. (*Gazella* (?) *porrecticornis*, Lyd.)	„	„
Bison sivalensis, Falc.	„	„
Bos acutifrons, Lyd.	„	„
— namadicus, F. & C.	Narbada, &c.	Pleistocene.
— planifrons, F. & C.	Sub-Himalaya	Higher pliocene.
— platyrhinus, Lyd.	„	„
— (?) sp.	Perim	„
* Bramatherium perimense, Falc. (*Sivatherium*, sp., Owen.)	„	„
Bubalus palaeindicus, F. & C.	Sub-Himalaya, Narbada, &c.	Higher pliocene and pleistocene.
——— platyceros, Lyd. (*B. sivalensis*, Rüt.)	Sub-Himalaya	Higher pliocene.

* Bucapra daviesi, Rüt.	Sub-Himalaya	Higher pliocene.
Camelopardalis sivalensis, F. & C.	Sub-Himalaya and	
(*C. affinis*, F. & C.)	Perim	"
Camelus sivalensis, F. & C.	Sub-Himalaya	"
Canis cautleyi, Bose.	"	"
—— curvipalatus, Bose.	"	"
Capra perimensis, Lyd.	Perim	"
—— sivalensis, Lyd.	Sub-Himalaya	"
(*Hemitragus sivalensis*, Lyd.)		
—— sp.	"	"
—— sp.	Tibet	Pleistocene (?).
‡ Cervus (? duvaucelli, Cuv.)	Narbada	"
—— (?) latidens, Lyd.	Sub-Himalaya	Higher pliocene.
—— simplicidens, Lyd.	"	"
—— sivalensis, Lyd.	"	"
—— triplidens, Lyd.	"	"
Chalicotherium sivalense, F. & C.	Sub-Himalaya and	
(*Anoplotherium sivalense*, F. & C.)	Sind	Pliocene.
(*Nestoritherium sivalense*, Wag.)		
Chœromeryx silistrensis, Pent.	Gáro hills	Higher pliocene.
(*Anthracotherium silistrense*, Pent.)		
Dinotherium indicum, F. & C.	Panjáb and Perim	"
—— pentapotamiæ, Falc.	Panjáb, Kách, and Sind	Pliocene.
—— sindiense, Lyd.	"	"
Dorcatherium majus, Lyd.	Panjáb	Higher pliocene.
(*Merycopotamus nanus*, Falc.)		
—— minus, Lyd.	"	"
* Enhydriodon ferox, F. & C.	Sub-Himalaya	"
(*E. sivalensis*, F. & C.)		
(*Amyxodon*, F. & C.)		
Equus namadicus, F. & C.	Sub-Himalaya and	
(*E. palæonus*, F. & C.)	Narbada	Higher pliocene and pleistocene.
—— sivalensis, F. & C.	Sub-Himalaya and (?) Perim	Higher pliocene.
‡ Euelephas indicus, Lin.	Plains and Burma	Prehistoric.
(*Elephas indicus*, Lin.)		
—— hysudricus, F. & C.	Sub-Himalaya	Higher pliocene.
(*Elephas hysudricus*, F. & C.)		
—— namadicus, F. & C.)	Narbada, &c.	Pleistocene.
(*Elephas namadicus*, F. & C.)		
Felis cristata, F. & C.	Sub-Himalaya	Higher pliocene.
(*F. grandicristata*, Bose.)		
(*F. palæotigris*, F. & C.)		
(*Uncia cristata*, Cope.)		
—— sp.	"	"
‡ —— (? tigris, Lin.)	Jamna and Narbada	Pleistocene.
Helladotherium duvernoyi, Wag.	Sub-Himalaya	Higher pliocene.
* Hemibos acuticornis, F. & C.	"	"
(*Amphibos acuticornis*, F. & C.)		
(*Leptobos acuticornis*, Falc.)		
—— antilopinus, F. & C.)	"	"
(*Amphibos antilopinus*, F. & C.)		
(*Leptobos antilopinus*, Falc.)		

Hemibos occipitalis, Fal.	Sub-Himalaya	Higher pliocene.
(*H. triquetricerus*, F. & C.)		
(*Bos occipitalis*, Falc.)		
(*Leptobos triquetricornis*, Falc.)		
(*Peribos occipitalis*, Lyd.)		
(*Probubalus triquetricornis*, Rüt.)		
* Hemimeryx blanfordi, Lyd.	Sind	Earlier pliocene.
Hippopotamus iravaticus, F. & C.	Sub-Himalaya and Burma	Higher pliocene.
(*Hexaprotodon iravaticus*, F. & C.)		
——— palæindicus, F. & C.	Narbada, &c.	Pleistocene.
(*Hexaprotodon namadicus*, F. & C.)		
(*Hippopotamus namadicus*, F. & C.)		
(*Tetraprotodon palæindicus*, F. & C.)		
——— sivalensis, F. & C.)	Sub-Himalaya	Higher pliocene.
(*Hexaprotodon sivalensis*, F. & C.)		
* Hippohyus sivalensis, F. & C.	"	"
——— sp.	"	"
Hippotherium antilopinum, F. & C.	Sub-Himalaya and Perim	"
(*Equus antilopinus*, F. & C.)		
(*H. gracile*, Myr.)		
——— theobaldi, Lyd.	Burma, Perim, and Sub-Himalaya	"
(*Sivalhippus theobaldi*, Lyd.)		
(*H. gracile*, Myr.)		
——— sp.	Tibet	Pleistocene (?).
* Hydaspitherium grande, Lyd.	Sub-Himalaya	Higher pliocene.
——— megacephalum, Lyd.	"	"
(*H. leptognathus*, Lyd.)		
Hyæna sivalensis, F. & C.	"	"
(*H. felina*, Bose.)		
——— ? sp.	Tibet	Pleistocene (?).
Hyænarctos sivalensis, F. & C.	Sub-Himalaya and Panjáb	Higher pliocene.
(*Ursus sivalensis*, F. & C.)		
——— palæindicus, Lyd.	Panjáb	"
(? *Dinocyon*.)		
Hyopotamus giganteus, Lyd.	Bhúgti hills	Earlier pliocene.
——— palæindicus, Lyd.	Sind	"
Hyotherium sindiense, Lyd.	"	"
Hystrix sivalensis, Lyd.	Sub-Himalaya	Higher pliocene.
Ictitherium sivalense, Lyd.	Panjáb	"
Leptobos falconeri, Rüt.	Sub-Himalaya	"
——— frazeri, Rüt.	Narbada	Pleistocene.
Listriodon pentapotamiæ, Falc.	Panjáb	Higher pliocene.
(*Tapirus pentapotamiæ*, Falc.)		
——— theobaldi, Lyd.	"	"
Loxodon planifrons, F. & C.	Sub-Himalaya	"
(*Elephas planifrons*, F. & C.)		
‡ Macacus rhesus, F. Cuv.	Plains	Prehistoric.
——— sivalensis, Lyd.	Sub-Himalaya	Higher pliocene.
——— sp.	"	"
Machairodus sivalensis, F. & C.	"	"
(*M. falconeri*, Pomel.)		
(*M. palæindicus*, F. & C.)		
(*Drepanodon sivalensis*, F. & C.)		
Manis sindiensis, Lyd.	Sind	Earlier pliocene.

	Mastodon falconeri, Lyd.	Panjáb & Sind	Pliocene.
	——— latidens, Clift. (*M. elephantoides*, Clift.)	Sub-Himalaya, Burma, Panjáb, and Sind	"
	——— pandionis, Falc.	Sub-Himalaya, Sind, Perim, and Deccan.	Pliocene and pleistocene.
	——— perimensis, F. & C.	Sub-Himalaya, Sind, and Perim	Pliocene.
	——— sivalensis, F. & C.	Sub-Himalaya	Higher pliocene.
	Meles, sp.	Panjáb	"
	Mellivora sivalensis, F. & C. (*Ursitaxus sivalensis*, F. & C.)	"	"
*	Merycopotamus dissimilis, F. & C. (*M. sivalensis*, F. & C.) (*Hippopotamus dissimilis*, F. & C.)	Sub-Himalaya and Burma	"
	Mus, sp.	Sub-Himalaya	Higher pliocene.
	—— sp.	Narbada	Pleistocene.
	Ovis, (?) sp.	Sub-Himalaya	Higher pliocene.
	——, (?) sp.	Tibet	Pleistocene.
*	Palæopithecus sivalensis, Lyd.	Panjáb	Higher pliocene.
	Palæoryx, (?) sp.	"	"
	Palæotherium, (?) sp.	"	Eocene.
	Pantholops, (?) hundesiensis, Lyd.	Tibet	Pleistocene (?).
	Portax namadicus, Rüt.	Narbada, &c.	"
	——— sp.	Panjáb	Higher pliocene.
	Propalæomeryx sivalensis, Lyd.	Sub-Himalaya	"
	Pseudælurus sivalensis, Lyd.	Panjáb	"
	Rhinoceros deccanensis, Foote.	Madras	Pleistocene.
‡	——— indicus, Cuv.	Madras and Narbada	Prehistoric and Pleistocene.
	——— namadicus, F. & C.	Narbada	Pleistocene.
	——— palæindicus, F. & C.	Sub-Himalaya	Higher pliocene.
	——— sivalensis, F. & C.	Sub-Himalaya and Sind	Pliocene.
	——— ——— var. gajensis, Lyd.	Sind	U. Miocene.
	Rhizomys sivalensis, Lyd. ((?) *Typholodon*, Falc.)	Panjáb	Higher pliocene.
*	Sanitherium schlagintweiti, Myr. (*Sus pusillus*, Falc.)	Sub-Himalaya and Panjáb	"
	Semnopithecus sub-himalayanus, Myr.	Sub-Himalaya	"
	——— sp.	"	"
	——— sp.	Jamna	Pleistocene.
	Sivameryx sindiensis, Lyd.	Sind	Earlier pliocene.
*	Sivatherium giganteum, F. & C.	Sub-Himalaya	Higher pliocene.
	Stegodon bombifrons, F. & C. (*S. orientalis*, Owen.) (*Elephas bombifrons*, F. & C.)	Sub-Himalaya and (?) China	"
	——— clifti, F. & C. (*S. sinensis*, Owen) (*Elephas clifti*, F. & C.) (*Mastodon elephantoides*, Clift.)	India, Burmá, China, and Japan	"
	——— ganesa, F. & C. (*Elephas ganesa*, F. & C.)	Sub-Himalayá and Narbada.	Higher pliocene and pleistocene.

Stegodon insignis, F. & C. (*Elephas insignis*, F. & C.)	Sub-Himalaya, Japan, China and (?) Narbada.	Higher pliocene and (?) pleistocene.
Sus giganteus, F. & C. (*Hippopotamodon*, Lyd.)	Sub-Himalaya and Narbada.	Higher pliocene and (?) pleistocene.
— hysudricus, F. & C.	Sub-Himalaya, Sind, and Perim	Pliocene.
‡ — prædicus, Gray. (*S. cristatus*, Wag.)	Madras	Prehistoric.
— punjabiensis, Lyd.	Sub-Himalaya	Higher pliocene.
Tapirus (?) sp.	Burma	"
* Tetraconodon magnum, Falc.	Sub-Himalaya	"
Tragulus sivalensis, Lyd.	Panjáb	"
Ursus namadicus, F. & C.	Narbada, &c.	Pleistocene.
—— sp.	Sub-Himalaya	Higher pliocene.
* Vishnutherium iravaticum, Lyd.	Burma and (?) Panjáb	"
Viverra bakeri, Bose (*Canis* sp., Baker and Durand.)	Sub-Himalaya	"

Note on the Bijori Labyrinthodont—*By* R. LYDEKKER, B.A., F.G.S., F.Z.S.

As it is always expedient to correct erroneous determinations as speedily as possible, I have thought it advisable to publish a preliminary note regarding the large labyrinthodont skeleton from the Bijori group of the Gondwánas[1], which has recently come into my custody. Careful 'development' has exposed a considerable portion of the palatal aspect of the skull, which was previously concealed by matrix. As I hope eventually to describe and figure this important and interesting specimen, which has hitherto been considered as probably belonging to *Archegosaurus*, in the "Palæontologia Indica," it will only be very briefly noticed on this occasion.

The skull, which is the only part that need now be mentioned, is triangular in shape, and has a length of about 11, with an extreme breadth of 8, inches. The orbits are oval and placed somewhat posteriorly. The teeth are small, subcylindrical, and regular; there are several larger "tusks" close to the symphysis of the mandible, placed (as in *Mastodonsaurus*, *Labyrinthodon*, and *Pachygonia*) interiorly to the row of small teeth. This character alone shows that the specimen cannot belong to *Archegosaurus*. The structure of the teeth seems to be less complex than in the first three of these genera, but more so than in the last. The skull is greatly produced at its postero-external angles, and has large epiotic cornua, thereby differing from *Mastodonsaurus*. The mandible has apparently no distinct post-articular process, but a well-developed internal articular buttress. The palatine foramina are large and approximated.

Except in the apparent absence of a distinct post-articular process to the mandible, the skull shows decided affinity to the first division of the Euglypta[2]; in that respect, however, it agrees with *Loxomma*, but is distinguished by the

[1] See "Manual," part I, p. 128.
[2] See "British Association Report," 1874, p. 150.

characters of the teeth and orbits. The specimen will almost certainly have to be referred to a new genus.

It may not be out of place to mention that in describing the lower jaw of *Glyptognathus fragilis*, represented in figure 1 of the plate accompanying my last notice of Gondwána labyrinthodonts[1], the specimen, from the presumed absence of a post-articular process, was inferred to belong probably to the Brachiopina. It should have been stated, assuming the correctness of the inference as to the absence of the process, that it probably belonged to the Brachiopina, or some of the subsequent sections of Professor Miall's classification[2].

Note on a skull of Hippotherium antilopinum, *by* R. LYDEKKER, B.A., F.G.S., F.Z.S.

Among a small collection of Siwalik fossils from Perim Island lent by Mr. Theodore Cooke, LL.D., F.G.S., of Poona, and transmitted to me for determination, there is a very fine example of the skull of *Hippotherium antilopinum.* The species was previously unknown from Perim, and this is the first known example of the skull. It shows the complete molar dentition of the left side. and is otherwise fairly perfect: I shall hope to give a further description of it on a future occasion.

The Lodge, Harpenden, Herts.

On the Iron Ores, *and* Subsidiary Materials *for the* Manufacture of Iron, *in the North-Eastern part of the* Jabalpur District; *by* F. R. MALLET, F.G.S., *Geological Survey of India.* (With a map.)

From time immemorial the Jabalpur district has held an important place amongst those centres where the smelting of iron has been carried on in the native method. Plentiful ores, extensive jungles for the supply of charcoal, and proximity to thickly populated alluvial tracts of country, combined to give Jabalpur a commanding position in the old days, before railways had brought the native hearths into an unequal struggle with the blast-furnaces of England. Even now iron is made on what, from the native point of view, must be considered a large scale, numerous furnaces being scattered over the iron-bearing portions of the district.

The advantageous central position of Jabalpur, now that it is in railway communication with the richest parts of the surrounding provinces, is too great to have escaped notice with reference to the manufacture of iron on European principles. As far as was known, ores and flux were to be had in abundance, and the means for distributing the manufactured iron to the surrounding markets was at hand. But the often-experienced difficulty of keeping large furnaces in blast with charcoal, and the absence of any available coal, were a deterrent to any decisive action.

[1] "Records," Vol. XV, p. 27.

[2] "British Association Report." loc. cit.

Within the last year or two, however, the discovery of workable coal by Mr. T. W. H. Hughes, in the immediate neighbourhood of the Jabalpur district, has given the question a new aspect. A line of railway from the new coal-field at Umeria to Murwára (Katni), on the East Indian line, has been proposed, and the preliminary surveys already executed.

The question of fuel, then, being in a fair way towards a satisfactory solution, it became important to ascertain whether the generally received opinion as to the abundance and excellence of the Jabalpur ores was fully borne out by fact. I was consequently directed, in the early part of this year, to visit the more important places where iron was known to occur, with a view to forming an opinion as to the extent of the deposits, and the feasibility of working them, and to collect samples for subsequent analysis. The question of flux and other subsidiary materials was also to be looked into. The following paper, then, embodies the results of my work in the field and laboratory.

The iron ores, for purposes of description, may be regarded with reference either to their mineralogical characteristics, their geological distribution, or their topographical position. The accompanying map, the geological work on which is mainly, and indeed, with reference to the area with which we are more immediately concerned, exclusively, due to surveys executed by Mr. C. A. Hacket in 1869-72, shows the distribution of the different series of rocks. It will be seen that between the great spread of Vindhyan sandstones on the north and Deccan trap on the south, both of which formations are almost barren of any metallic wealth, there is a belt, some 30 miles wide, where a very varied and intricately disposed assemblage of rocks occurs. It is just here that the band of iron-bearing transition strata, which stretches eastwards for more than 200 miles through the Son Valley, comes in contact with the thickly populated alluvial belt through which the Narbadda flows westwards for about the same distance. Hence one of the most important advantages which the iron-smelters of Jabalpur have enjoyed. Hematite ores similar to those of Jabalpur are known to occur largely in the wild country to the east; but there are not the same facilities there for disposing of the manufactured product.

The formations just mentioned include—

Alluvium.
Rock laterite.
Deccan trap.
Lameta group.
Upper Gondwána.
Coal measures.
Tálchir group.
Upper Vindhyans.
Lower "
Bijáwar or transition series.
Gneiss.

The Bijáwar series and the rock laterite are those with which we are more immediately concerned now, for it is in them that nearly all the iron ore is contained[1]. By reference to the map, then, one sees at a glance the general lie of the iron-bearing tracts, which are those coloured respectively purple and burnt sienna, although it is only in certain portions of those areas that the ores are found. The Bijáwar ores occur more especially in the Parganas Khumbhi and Gosulpur, while the Pargana Bijerágogarh contains the greater portion of the lateritic ores.

Mineralogically considered, the iron ores are almost exclusively varieties of hematite and limonite (or red and brown hematite), the former being especially characteristic of the Bijáwars, and the latter of the newer formation. They may be classified thus—

- BIJÁWAR ORES
  - 1, *Hematite*
    - Schistose hematite.
    - Micaceous iron.
    - Jasper-hematite[2].
    - Semi-ochreous hematite.
    - Manganiferous hematite.
  - 2, *Limonite.*
- LATERITE ORES
  - 1, *Limonite*
    - Pisolitic limonite, breaking with smooth conchoidal fracture.
    - Pisolitic limonite, breaking with rough uneven fracture.
    - Ordinary laterite, some parts of which contain a high percentage of iron.
  - 2, *Hematite.*

Magnetite has been found in small crystals disseminated through the hematite beds of Sehora, but I am not aware of its occurring anywhere in such quantity as to entitle it to be included in the above list as an ore.

BIJÁWAR ORES.

The Bijáwar series has been subdivided by Mr. Hacket thus (in descending order):—

Chandardíp group.
Lora ,,
Bhítri ,,
Majhauli ,,

It is in the inferior strata of the Lora group (so called from the Lora range east of Sehora) that all the most important existing mines are sunk[3]. "All the iron-workings," says Mr. Hacket "are situated near the base of the (Lora) group, where the quartz bands[4] are absent, and the rocks consist almost entirely of micaceous iron, or mixed with a few bands of clay. The Jauli mines are so situated, as also those of Mangela, and at Agaria in the Majgaon hills, and also

[1] Some ore also occurs in the Gondwána beds, but it is "very impure and requires much selection and cleaning" and is "very rarely worth working" (J. G. Medlicott, Memoirs, Geological Survey of India, Vol. II, p. 278).

[2] *Vide* p. 100.

[3] Here, and subsequently, in reference to native operations, I use the word 'mine' to express an excavation where ore is extracted, irrespective of its form. Underground workings are rather the exception than the rule, the majority of the excavations being irregular open pits.

[4] *Vide* p. 100.

in the hills west of the 'marble rocks'. This band of rich iron appears to be very constant in the section, but, being softer than the rocks above, is mostly worn away, and covered by the alluvium, or débris from the ridges of the harder rocks; but that the band exists is shown by the pieces of rich iron strewn along the line." [1]

A few workings in the Majhauli hills (near the western edge of the map) are situated in rocks of the Bhítri group, but these are of very secondary importance [1].

Probably the most extensively worked cluster of mines in the district are those situated in the group of low irregular hills south of Sarroli and Majgaon (8 miles south-east of Sehora), and as the iron-bearing strata are exposed there more clearly, and on a larger scale, than in any other localities that I have visited, it will be convenient to take that neighbourhood as a starting point in any detailed descriptions.

Hill ½ mile south of Agaria.

The hill half a mile south of Agaria (4 miles west-south-west of Sarroli) appears to be formed entirely of iron ore. The strata have a low irregular dip towards the south. The highest beds, *i.e.*, those on the south side of the hill, where there are numerous pits, are of evenly laminated micaceous iron, interbanded with occasional argillaceous layers. The rock is so soft that it can be powdered between the fingers, and is simply dug out with ordinary *kodalis*. But the greater portion of the ore, constituting the lower beds, is schistose hematite, which is harder than the micaceous iron, although easily worked on account of its fissile character. Numerous pits have been sunk into it also. There is a thin skin of laterite on the top of the hill, which is, in great part at least, and I believe wholly, due to alteration of the iron-schist *in situ*.

As this hill is about a third of a mile long, flat-topped, and wide, and not far from 100 feet high, the quantity of ore available by open workings, with free drainage, is enormous. As a very rough estimate, the cubic contents of the hill may perhaps be taken at $\frac{600 \times 480 \times 30}{2}$, or about four million cubic yards[2], which is equivalent to about fourteen million tons of ore. Even then if a liberal deduction be made for possible concealed bands of useless rock, the remaining figures will represent an immense amount of ore.

A sample of schistose hematite from the northern side of the hill yielded on analysis—

Ferric oxide	97·54 = Iron 68·28
Phosphoric acid	·12
Sulphuric acid	trace
Sulphur	traces
Loss on ignition [3]	·89
Ignited insoluble residue	1·21
Alumina and undetermined	·24
	100·00

[1] MSS. report, 1870-71.

[2] The product of the dimensions of the hill is divided by 2 to allow for the slopes and irregularities.

[3] This and the other ores analysed were air dried. The loss on ignition, therefore, includes hygroscopic moisture, as well as, in the case of the hydrous ores, chemically combined water.

Ridge at Agaria.

In the low ridge which runs westward from Agaria a band of hematite schist, several yards thick, is visible along the crest. Elsewhere the rock is obscured by talus, &c. Except, however, near the base of the southern slope, where pieces of ferruginous sandstone are strewn, the *debris* on the ridge is entirely of hematite schist, so that considerably more ore may exist than is actually seen. The ridge is perhaps 40 to 50 feet high, and comparatively wide, with gentle slopes. Even if the hematite band is not thicker than the exposed strata, a large amount of ore is available in the ridge. The dip, as seen about half a mile west of the village, is to the south at 40°—50°.

Hills south-east of Agaria.

In the hills south-east of Agaria I observed runs of ore in two or three places, but nothing of much importance. At the western end of the Jhíti ridge some limonite schist is seen, dipping S. 20° E. at 40°, but no good section is exposed. This, as well as other Bijáwar limonite ores, which are of rather unfrequent occurrence, may possibly be due to hydration of hematitic strata near the surface. At the southern base of the hillock just west of Kurumukur, jaspery quartz schist interbanded with micaceous iron is seen. The hillock is capped by laterite, and similar rock is to be seen in some of the hills to the north-east of the same village. These hills are low and featureless, with little or no other rock visible. It is not at all improbable, however, that the laterite is due to superficial alteration of iron ore, and that there is a considerable, perhaps a large, quantity of the latter in the hills in question.

Sarroli.

There are two low hillocks close to Sarroli, one three-quarters of a mile somewhat south of west, and the other a mile south-south-west from the town. The former of these is composed of schistose hematite and micaceous iron, the beds of which have an irregular strike, corresponding on whole with the direction of the hill, and an uncertain dip at high angles. There is a skin of laterite in places due, I have no doubt, to superficial alteration of the ore.

The northern part of the other hill is also composed of iron ore, which has an irregular dip, apparently towards the south as a whole. The southern part of the hill is formed of hornstone. The lower beds of ore, *i.e.*, those in the most northern part of the hill, are of hard micaceous iron passing into schistose hematite, while the upper strata are of soft, crumbly, finely laminated micaceous iron, with some interbanded argillaceous layers. It will be observed that the section here is similar to that in the hill half a mile south of Agaria—soft crumbly ore above and harder beds beneath—and I do not think there can be much doubt that the strata in the two localities belong to the same horizon. There are two rather large excavations in the upper beds; that to the south-east is known as the Sarroli mine, and that to the north-west as the Partábpur mine (from a village close by which is not marked on the map).

As a rough estimate of the amount of ore available by open workings, with free drainage, in the Sarroli hills, the cubic contents of the northern may perhaps be taken at $\frac{600 \times 150 \times 18}{3}$, or about 500,000 cubic yards, and that of the iron-bearing part of the southern at $\frac{300 \times 300 \times 17}{3}$, or about the same amount. This is equivalent to about 1,700,000 tons of ore in each hill, or say three and a half million tons in both together. In this estimate, as in that for the hill south of Agaria, no account is taken of the ore which could be raised from open workings beneath the level of the surrounding country. From such workings an immense amount of ore could be obtained.

A sample of the crumbly micaceous iron from the Partábpur mine, taken as it was being loaded on to buffaloes for transmission to the neighbouring furnaces, yielded—

Ferric oxide	92·21 = Iron 64·55
Phosphoric acid	·07
Sulphuric acid	trace
Sulphur	trace
Loss on ignition	1·86
Ignited insoluble residue	4·50
Lime, alumina and undetermined	1·36
	100·00

The harder ore from the north end of hill gave—

Ferric oxide	97·16 = Iron 68·02
Loss on ignition	1·30
Ignited insoluble residue	·89
Undetermined [1]	·65
	100·00

Jauli.

The largest iron mine in the district is that near Jauli, somewhat less than a mile south-east of the village (3 miles south-east of Sarroli). The ore is a semi-ochreous hematite, in which a slightly schistose structure is often apparent. Hematite with metallic lustre also occurs, but is quite subordinate to the more ochrey kind. The ore is interbanded with quartzose layers, which in some places greatly exceed the ferruginous part of the rock. In other places they are comparatively rare, and in the best ore they are still less common. These layers vary from a fraction of an inch to several inches in thickness. The beds are vertical, the strike, where best seen, being N. 40° E. A rough measurement showed the beds exposed to have a thickness of about 150 feet, but in estimating the thickness of ore, a deduction must be made as an allowance for the quartzose portion just alluded to.

The ore has been very largely worked, the mine being nearly 100 yards long by 50 yards broad, and perhaps 50 feet deep. I was informed by Mr. Olpherts' agent in charge of the mine, that it is not flooded in the rains; it is a sort of deep trench (the length of which coincides with the strike of the rock) in which water would accumulate if it did not soak away subterraneously, or evaporate, quicker than it entered. The surrounding country is an undulating one, and without actual levelling it would be impossible to say to what extent free drainage could be depended on for more extensive operations.

It is from picked ore from this mine that Mr. W. G. Olpherts' 'metallic paint' is made, by grinding to an impalpable powder.

[1] In this, and subsequent analyses, in which phosphorus and sulphur are not given separately, any present is included in the undetermined portion of the ore.

Some distance, perhaps a quarter of a mile, to the north-east of the above mine, there is an old abandoned one. The ore exposed is not as rich as that in the mine now worked, and naturally so, as previous to abandonment all the best ore exposed would be removed. The beds dip E. 30° S. at 60°, the strike therefore being nearly the same as in the newer mine. Mr. Hacket considered the ore in both mines to belong to the same band, and one can scarcely doubt that such is the fact; but the ore is so soft that it makes no show at the surface, and hence cannot be traced along the outcrop. If the band is continuous, however, for even a quarter of a mile only, with anything like the thickness it has in the present mine, a very large amount of ore is hidden beneath the surface.

An average sample of the Jauli ore, taken as it came, and including the inter-banded quartz, yielded on analysis—

Ferric oxide	75·69 = Iron 52·98.
Phosphoric acid	·10
Sulphuric acid	traces.
Sulphur	traces.
Loss on ignition	1·59
Ignited insoluble residue	22·32
Manganese oxide, lime and undetermined	·30
	100·00

By the aid of some picking, however, a much purer ore can be obtained. A sample assayed by Mr. A. Tween gave 97·86 per cent. of ferric oxide = 68·50 of iron, and some of Mr. Olpherts' paint gave 97·10.

Ores of the Sarroli hills bedded, not fault, rock.

Before leaving the ores of this neighbourhood, I ought to mention that the hematite of Jauli and Agaria, as well as of the hills close to Sarroli, is most distinctly a bedded rock, having generally (except at Jauli, where it is less strong marked) a highly schistose character. Locally indeed the rock is crushed and recemented, and this crushing may have taken place along lines of faulting (probably merely local slips). But except in such very limited sense the ore is most certainly not a fault rock. The point is one of practical importance with reference to the probable persistency of the ore, and is alluded to as the reverse has been previously stated[1].

Lora Hills.

The most prominent rock in the Lora range (east of Sehora) is a ferruginous siliceous schist, composed of alternating layers of micaceous iron and quartz, which is usually of a red jaspery type. The layers are of irregular thickness, varying from a small fraction of an inch to an inch and upwards. For want of a better name, and to avoid circumlocution in referring to it, this rock may perhaps be called jasper-hematite schist. If it were marked as an iron ore, the Lora range (as well as many other lines of hill) should be streaked with gold from end to end. But a large proportion of the rock contains too great an amount of silica to allow of its being smelted with advantage, more especially when ores practically free from silica are to be obtained in abundance. Only those places, therefore, are marked with gold in which I have myself seen good workable ore.

[1] Memoirs, Geol. Surv. of India, Vol. II, p. 278.

North of Mangola.

At the termination of the range north of Mangola a band of jasper-hematite is exposed *in situ* along the crest. Lower down the slopes there is a talus of the same rock, amongst which pieces of micaceous iron 2 or 3 inches thick, or more, and free from siliceous layers, are not uncommon. But the beds are not exposed sufficiently for one to form an opinion as to whether there is any considerable quantity of ore.

Gogra and Dauwai.

The hill half a mile north of Gogra is formed mainly of jasper-hematite. Near the base of southern slope there are a number of shallow ore pits[1], but they are only in talus, not in the rock *in situ*. The miners seek for the small bits of ore which can be used at once in the furnaces, and leave the large lumps, which would require the labour of breaking up. The ore is a manganiferous micaceous hematite, containing a varying proportion of interbanded jaspery quartz. It is a siliceous ore, although not very highly so. As the manganiferous band is entirely concealed beneath the talus, no estimate can be made of its thickness. Judging, however, from the large amount of *debris*, it seems probable that the thickness is considerable. As the loose ore must either lie directly over that *in situ*, or else have come down hill, and as the pits extend 20 or 30 feet (vertically) from the base of the hill, probably a large amount of ore is obtainable by dry open workings, whether these be through a deep mass of talus or into solid rock.

The proportion of manganese varies much, as can be seen from the outward appearance of the ore. In some specimens of the micaceous iron, the presence of manganese is scarcely apparent to the eye; in others, the ore shows by its dark colour that it contains a large amount, and in the highly manganiferous portions psilomelane occurs in irregular segregations. A carefully chosen average sample, made up of a large number of small pieces taken from different pits, yielded—

Ferric oxide	66·33 = Iron 46·43
{ Manganese (with traces of cobalt)	12·26
{ Oxygen	6·83
Phosphoric acid	·27
Sulphuric acid	·03
Sulphur	trace.
Ignited insoluble residue	9·55
Lime, alumina, water and undetermined	4·76
	100·00

The manganese exists, in large part at least, in the form of psilomelane, occurring in irregular segregations, or more minutely disseminated through the rock.

The Gogra miners told me (and Mr. Hacket mentions the same thing) that the ore from these pits produces a hard steely iron, used for making edged-tools, &c., while that from the mines in the Sarroli neighbourhood yields a soft iron, used largely for '*karrais*' (shallow basins for making *chupatis* in, &c.). The difference is no doubt to be attributed to the manganese in the former.

[1] Those to the west belong to the village Gogra, and those to the east to Dauwai.

Kuthola.

The ridge running eastward from Kuthola (1 mile south-east of Sehora) is formed mainly of jasper-hematite. At the gap where the railway passes, the strata dip at a high angle towards the south. In the low hill just west of the railway station (Sehora road), the beds in which seem to be higher in the section, as the rocks actually lie, than those just mentioned, manganiferous hematite schist, with psilomelane, is visible. The rock is more earthy and impure-looking than that at Gosulpur, which will be described presently, and contains a considerable amount of interbanded jasper and quartz. No great thickness is exposed, but the outcrop is of some importance, as indicating the position of the manganiferous band.

Where the Deccan road passes the end of the ridge, jasper-hematite with hornstone is visible *in situ*, and pieces of psilomelane, &c., are scattered about.

Gosulpur.

On the northern slope of the hillock, about 300 yards N. 15° W. from the Dák Bungalow at Gosulpur, a strong band of manganiferous micaceous iron outcrops. In a little nalla at the foot of the hill the following section is exposed:—

	Feet.
Clay-slate, seen about	50
Somewhat ferruginous quartz schist	5
Obscured	20
Manganiferous micaceous iron	15 ?
" quartz schist	5
" micaceous iron, seen	35

The total thickness of ore actually seen being about 50 feet. The section is given in descending order, as the rocks lie, the dip being about 60° to N. 30° W.

The hillock just mentioned forms the eastern extremity of a low scarp, running from Gosulpur to W. 30° S. The scarp is capped by several yards of rock laterite, but lower down the slope (which faces to N. 30° W.) the mangano-ferruginous band outcrops in several places. It is fairly seen at intervals for about a third of a mile, and reveals its presence more obscurely, by occasional small outcrops, and by loose fragments, for at least a quarter of a mile more. As in the first third of a mile the outcrop is well above the plain (averaging perhaps 30 feet or so), there is, unless the band thins out considerably immediately westward of Gosulpur, which is not likely, some hundreds of thousands of tons to be had by dry open workings, and probably some millions by going deep enough.

The appearance of the rock shows (as at Gogra) that the proportion of manganese is very variable. The greater portion of it, at least, exists in the form of psilomelane, occurring partly as linings to small cavities in the rock, and in irregular segregations and masses, some of which contain some cubic feet of mineral. I am somewhat inclined to think that the psilomelane is most abundant where the schist has crushed and re-cemented, psilomelane being the cementing material. A sample of the more manganiferous part of the schist afforded 16·02 per cent. of manganese (with a little cobalt), while the psilomelane gave 88·20 per cent. of available peroxide.

Reviewing the above details, it will be seen that manganiferous micaceous hematite has been found in several places along the southern side of the Lora range. One can scarcely feel much doubt as to there being a continuous band in that position. It is highly probable that the Gosulpur ore belongs to the same horizon, but whether it is a direct continuation of the same outcrop or not is more doubtful. The strata in the Lora range have a general dip towards the south-south-east at high angles, while the beds at Gosulpur dip N. 30° W. at about 60°. This may be a mere local feature, or it may indicate that the Lora and Gosulpur outcrops are on opposite sides of a synclinal flexure.

There does not appear to be any reason why the Gosulpur and Lora manganiferous ore should not form a suitable material for the manufacture of spiegeleisen. Although part of the manganese occurs in distinct segregations, a large proportion of it is minutely disseminated through the ore.

On the slope of the hillock at Gosulpur above mentioned, a little below the outcrop of the manganiferous ore, there is a band of limonite not less than 15 feet thick. It can be traced westwards for about the same distance as the other ore, to which it runs parallel. Some parts are very massive, the rock lying about in large blocks; others present a schistose appearance. At the time I took this to be a bedded Bijáwar rock, but I am not prepared to assert positively that it is so. Whether it be or not, a considerable quantity of ore (containing, however, a rather high percentage of phosphorus) is to be obtained from it. It yielded on analysis—

Ferric oxide	81·57 = iron 57·10
Phosphoric acid	1·69
Sulphuric acid	0·00
Sulphur	traces [1]
Loss on ignition	10·91
Ignited insoluble residue	4·08
Lime, alumina and undetermined	1·75
	100·00

LATERITIC ORES.

The pisolitic ores occur on a horizon near the base of the lateritic strata. "The bottom beds (of the group) consist of a coarse ferruginous sandstone, formed of rounded bits of quartz, sometimes as large as a pea, embedded in a hard ferruginous paste. Above this there are some beds of fine ferruginous earthy sandstone, containing badly preserved leaf-impressions. Resting upon these in some sections, there are several feet of a rich oolitic iron ore, covered by red, white, and purple clays, with bands of a coarse ferruginous sandstone interbedded, the whole capped by the ordinary rock laterite."[2]

There are two main varieties of pisolitic ore, one of which breaks with a smooth conchoidal fracture and shining surface; the other with a rough uneven fracture and dull lustreless surface. In the former the hardness and tenacity of the spherules, and of the cement in which they are embedded, are about equal, so that fracture takes indifferently through both parts of the rock. The difference of fracture in the other variety is due partly to the cement, and also the spherules,

[1] ·003.

[2] C. A. Hacket, MSS. report, 1871-72.

breaking with a dull uneven surface; partly to some of the spherules being dragged out of their sockets unbroken, so that the surface of the rock shows a number of roundel prominences and depressions. The conchoidal-fractured limonite is hard and brittle, the other much softer, and sometimes quite friable.

The spherules of the former vary in size from that of large peas downwards, so that the rock passes into oolitic limonite. Intimately associated with it in many sections is a highly ferruginous sandstone, which, when looked at under the lens, is seen to be composed of minute grains of quartz with an abundant limonitic cement. Sometimes the rock is free from spherules of limonite; more frequently such are scattered through it more or less abundantly. Thus it passes into the rich pisolitic ore in which grains of quartz are sometimes visible between the spherules, though more frequently the cement is, like the spherules themselves, purely limonitic. The sandstone and pisolitic ore are often found in juxta-position, with a sharp line of division between the two.

An immense number of small pits, most of which are now abandoned, are scattered over the lateritic area. The majority of those I visited are in the neighbourhood of Bijori (7 miles east-south-east from Murwára) and in the Kanhwára hills.

There is a quarry a quarter of a mile S. 15° W. from Bijori from which Mr. W. G. Olpherts obtained some of the ore smelted in his experimental works at Murwára. The section at one end comprises—

Bijori.

	Ft.	In.
a. Surface soil	1	0
b. Lateritic *debris*	1	6
d. Pisolitic limonite with conchoidal fracture	0	11
e. Ochreous, somewhat pisolitic, limonite with rough fracture	0	4
f, g. Semi-ochreous red oxide of iron, in onion-like nodules several inches in diameter	0	8
h. Lithomargic clay	0	7
i. Soft friable sandstone, seen	0	7

One hundred feet to the east, at the other end of the quarry, the section is as follows—

	Ft.	In.
a. Surface soil	1	0
b. Lateritic *debris*	1	0
c. Soft pisolitic limonite with rough fracture	3	4
d. Pisolitic limonite with conchoidal fracture	0	10
e. Ochreous, somewhat pisolitic, limonite with rough fracture	0	5
f. Pisolitic limonite with conchoidal fracture	0	4
g. Ochreous, somewhat pisolitic, limonite with rough fracture	0	5
h. Lithomargic clay, seen	0	10

In comparing the above two sections it will be observed that the band of semi-ochreous red oxide of iron in the first corresponds to *f* + *g* in the second, or to one or other of them, the other having died out. In either case there is a change in mineral character laterally, which change may be either original or secondary. The absence of *c* in the first section is merely due to denudation.

About a mile south of Bijori there is another quarry, which has been worked by Mr. Olpherts. The section at the eastern end comprises—

	Ft.	In.
a. Surface soil	1	0
b. Disintegrated laterite, or lateritic *débris*	2	8
c. Disintegrated laterite with one or two layers of highly ferruginous sandstone, and thin seams of pisolitic limonite with conchoidal fracture	0	9
d. Pisolitic limonite with conchoidal fracture	0	3 to 4
e. Soft pisolitic limonite with rough fracture	1	9
f. Pisolitic limonite with conchoidal fracture	0	½
g. Soft pisolitic limonite with rough fracture	1	10
h. Limonite, with conchoidal fracture; pisolitic in the upper part, passing into oolitic lower down	0	11
i. Laterite, seen	1	3

At the other end of the quarry, 22 feet to the west, the band *h* is represented by—

		Ft.	In.
h.	Pisolitic limonite with conchoidal fracture	0	3
	Soft pisolitic limonite with rough fracture	0	4
	Oolitic limonite with conchoidal fracture	0	4½

The middle 4-inch band, therefore, dies out in a very short distance. In the western part of the quarry, also, the band *d* is represented by a layer, about equally thick, of compact brittle limonite. It is further noticeable in this section that ordinary laterite underlies the pisolitic ore.

An average sample from the band *h* gave on analysis—

Ferric oxide	81·20 = Iron 56·84
Phosphoric acid	1·41
Sulphuric acid	trace.
Sulphur	trace.
Loss on ignition	13·42
Ignited insoluble residue	1·29
Alumina, lime and undetermined	2·68
	100·00

On the north side of the village 3 feet 4 inches of soft pisolitic limonite, with rough fracture, is exposed, with the base not seen. This afforded—

Ferric oxide	71·72 = Iron 50·20
Loss on ignition	14·68
Ignited insoluble residue	7·94
Undetermined (alumina & lime in part)	5·66
	100·00

In an old pit half a mile east of Bijori 2 feet of ore of the same kind is exposed.

There are a number of abandoned pits about 300 yards north of the village, in one of which the following section was measured:—

	Ft.	In.
Surface soil	1	6
Soft pisolitic limonite with rough fracture	1	5
Pisolitic limonite with conchoidal fracture	0	1
Soft pisolitic limonite with rough fracture	0	7
Ochreous pisolitic limonite with rough fracture	0	8

	Ft.	In.
Pisolitic limonite with conchoidal fracture; the amount of cement, between the spherules increasing in amount downwards until the rock passes into highly ferruginous sandstone	0	7 to 8
Soft pisolitic limonite with rough fracture	0	6
Friable ferruginous sandstone with some thin irregular hard layers, seen	1	6

Majhgaon.

About half a mile south-west of Majhgaon, some ferruginous beds are very imperfectly seen in a nalla.

	Ft.	In.
Pisolitic limonite with conchoidal fracture, not less than . . .	1	6?
Arenaceous semi-ochreous hematite, in beds of irregular thickness, seen	4	0

The lower beds are considerably contorted on a small scale.

On the south-west side of the village, in an old pit, about 2 feet of oolitic limonite, mostly of the soft variety, underlies some 4 feet of lateritic *debris*. The base of the ore is not visible.

Bhadora.

Three quarters of a mile south-west of Bhadora there is a group of old pits, in the largest of which the following section was measured :—

	Ft.	In.
Surface soil, &c.	3	0
Bed of earthy limonite, with faint plant impressions	0	10
Lithomargic clay	3	0
Oolitic limonite, softer and less highly ferruginous than that below	2	0
Oolitic limonite, rather soft and breaking with rough fracture, seen	1	0

Summarizing the preceding sections, we find the thicknesses of ore actually seen, to be as follows :—

	Pisolitic limonite with conchoidal fracture.		Pisolitic limonite with rough fracture		Non-pisolitic limonite.		Hematitic ore.		TOTAL.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
½ mile S. 15° W. from Bijori	1	2	4	2	...		..		5	4
1 mile south of Bijori	1	3	3	7	...		...		4	10
North side of Bijori	...		3	4	...		...		3	4
½ mile east of Bijori	...		2	0	...		...		2	0
300 yards north of Bijori	0	8	2	9	...		...		3	5
½ mile south-west of Majhgaon . . .	1	6?	...		...		4	0	5	6?
South-west side of Majhgaon	...		2	0	...		...		2	0
¾ mile south-west of Bhadora . . .	...		3	0	0	10	...		3	10

In the sections which are best seen there is about 5 feet of ore. In the others either a portion of the ore has been denuded away from the top, or the lowest beds are not visible.

With reference to the important question whether the iron-bearing strata are continuous throughout the area over which the pits above noticed are scattered, it would be perhaps rash to express an unqualified opinion. The strata are most obscurely seen, being rarely visible except in the old pits, and seldom in them even except by clearing out the rubbish, by which they are more or less choked up. But I am certainly strongly inclined to believe that the ore will be found to occur continuously at the same horizon, although the details of the section may vary in different localities. Some of the sections given above show slight differences within a few yards even, but those in which the rocks are best seen agree in there being a foot or so of limonite with conchoidal fracture, covered by a thicker band of the softer kind of ore.

The map scarcely indicates the form of the ground correctly. There is low ground, occupied by alluvium, on the borders of the streams, sloping gently upward to more elevated ground, where the surface rock is laterite, rather than definite hills and valleys. The ore beds generally occur near the foot of the lateritic slope, a little above the level of the alluvium. They have probably, therefore, been denuded away from some, at least, of the alluvial hollows. But these hollows occupy a far less area than the lateritic ground. In the latter I believe the ore will be found continuously; at or close to the surface in the lower ground, and obtainable by open workings, but in the more elevated tracts probably beneath such a depth of overburden as to necessitate shallow mines. The amount of ore must be very large. A continuous bed of even one yard only would contain more than eight million tons to a square mile.

About a mile north of Emelia there are two quarries about 100 yards apart. That to the north was worked last year, and a considerable heap of ore was stacked at the time of my visit. The section includes—

Emelia.

	Ft.	In.
Surface soil	0	2
Highly ferruginous sandstone	1	3
Disintegrated ordinary laterite	1	3
Pisolitic iron ore, seen	4	0

The floor of the quarry is on the ore, so that the total thickness of the latter is not apparent. The strata dip about N. N. W. at 5°. The ore is somewhat different to any that I have seen elsewhere. It consists of spherules of limonite (having an onion-like structure, and ranging up to an inch, or even more, in diameter, but usually not exceeding half an inch) which are embedded in a semi-ochreous cement consisting mainly of brown, but partly of red, oxide of iron. Most of the spherules on the surfaces of fracture remain unbroken, being torn out of their sockets on one side.

In the other quarry the same beds are seen less fully.

	Ft.	In.
Surface soil	0	9
Highly ferruginous sandstone	1	0
Disintegrated ordinary laterite	0	6
Pisolitic iron ore, seen	1	3

The ore is similar to that in the first quarry, except that the cement contains more red oxide. Dip north-west at 5°.

The ore in these quarries being on rising ground, and, where it is now exposed at least, close to the surface, is favourably situated for open workings. An average sample from the first-mentioned gave—

Ferric oxide	77·81 = Iron 54·47
Manganese (calculated as Mn_2O_3), with traces of cobalt	1·54
Phosphoric acid	·82
Sulphuric acid	traces.
Sulphur	traces.
Loss on ignition	13·20
Ignited insoluble residue	3·27
Alumina, lime and undetermined	3·36
	100·00

Jhijri.

On the rising ground about a mile west-south-west of Jhijri several shallow pits have been sunk, but they are now abandoned. Lumps of ore are freely scattered about over the surface, and here and there a thin bed is visible *in situ*. The thickest I saw included 10 inches of pisolitic limonite with conchoidal fracture.

Kailwára.

At the base of an outlying hillock of laterite, about half a mile north-west of Kailwára, there is a band of ore, similar to that near Jhijri, which has a thickness of not less than 20 inches.

Murwára.

In a nalla, close to Mr. Olpherts' paint mill on the Katni, a mass of somewhat earthy limonite, mixed with red oxide, appears from beneath the alluvium for a distance of about 20 yards. It has an apparent schistose structure and is unlike any lateritic ore that I am acquainted with. On the other hand, it is very improbable that the Bijáwar rocks should appear at the surface, which they could only do by very peculiar faulting, so that I feel uncertain as to the relations of the ore. It afforded—

Ferric oxide	75·23 = Iron 52·66
Loss on ignition	9·02
Ignited insoluble residue	11·08
Undetermined (alumina and lime in part)	4·67
	100·00

Kanhwára hills.

The Kanhwára hills (6 miles north-east of Murwára) form a level plateau bounded by a sharply defined escarpment. The surface rock on top is ordinary laterite, while bands of rich iron ore outcrop along the face of the slope.

Pisolitic limonite, in great part of the kind with conchoidal fracture, forms a strong band at the top of the escarpment a quarter of a mile W. 20° N. of Pilongi. There is little or no overburden on it.

At the foot of the ghát, half a mile N. 20° W. of Piprehta, a bed of similar ore not less than 2 feet thick is visible.

Not far from the top of the scarp above Piprehta there is a strong band of the same kind of ore. There appears to be another lower down, but the section is obscurely seen.

On the slope of the projecting spur, a quarter of a mile south-east of Piprehta, there are some old pits. In one of them the following section was measured:—

	Ft.	In.
Pisolitic limonite, mainly of the kind with conchoidal fracture, in part somewhat ochreous, seen	2	10
Coarse ferruginous sandstone	1	[illegible]
Compact, or slightly ochreous, limonite . . .	0	[illegible]
Do. red oxide of iron	0	[illegible]
Lithomargic clay, seen	1	[illegible]

there being 3 feet 3 inches of ore, with the top of the main band missing through denudation. The ore is 15 feet (vertically) below the top of the hill, which is about 70 yards to the north—

A sample from the main seam yielded on analysis:—

Ferric oxide	82·18 = iron 57·52
Phosphoric acid	·76
Sulphuric acid	trace
Sulphur	traces
Loss on ignition	13·89
Ignited insoluble residue	1·57
Alumina, lime and undetermined .	1·60
	100·00

It will be noticed that this, as well as the other lateritic ores analysed, contains a much higher percentage of phosphorus than the hematites. In the latter the phosphoric acid ranges from ·10 to ·27 per cent.; in the former from ·76 to 1·41 per cent.

At the foot of the hill, below the pits just mentioned, there is a strong band of oolitic and pisolitic limonite with conchoidal fracture.

To the north-west of Kamtarra (a village 1 mile south of Mohári) there are some old pits 25 feet above the foot of the escarpment, which is 70 feet high. The ore is pisolitic limonite with conchoidal fracture, and is not less than 12 inches thick. There seems to be more than one band of ore besides that in the pits, but the section is very obscure. Large quantities of loose ore are strewn on the hill-side at different levels.

Just west of Mohári the hill is capped, with no overburden, by 2 feet 4 inches of oolitic limonite with conchoidal fracture. There are some old pits here, and others about half way down the hill.

In the nalla just north of Mohári there is—

	Ft.	In.
Oolitic limonite with conchoidal fracture, seen	0	9
Slightly arenaceous limonite, in thinnish beds containing plant impressions	0	[illegible]
Ferruginous sandstone, seen	1	6

Near the bottom of the ghát, half a mile north-west of Mohári, there is a band of pisolitic limonite with conchoidal fracture, seemingly about 2 feet thick. Higher up there is another strong band of similar ore.

On the slope above Kanhwára 2 feet 6 inches of same kind of ore, but somewhat ochreous in part, outcrops in one place.

About half a mile south of Kanhwára the surface rock, at some little distance from the foot of the escarpment, is pisolitic limonite with conchoidal fracture.

On comparing the above sections it will be seen that there is one band of ore near the top of the escarpment, another at the foot of it, and a third in an intermediate position. The thicknesses, in as far as I was able to ascertain them, were—

	Top seam.	*Middle seam.*	*Bottom seam.*
½ Mile W. 20° N. of Pilongi	Strong band	...	.
½ „ N. 20° W. of Piprehta	...	..	Not less than 2 feet.
Piprehta	Strong band	?	...
½ Mile south-east of Piprehta	Not less than 3 feet 3 inches.	...	Strong band.
North-west of Kamtarra	.	Not less than 1 foot.	...
West of Mohári	Not less than 2 feet 4 inches.	?	. .
North of Mohári	...	...	Not less than 1 foot 6 inches.
North-west of Mohári	...	Strong band	2 feet ?
Kanhwára	...	2 feet 6 inches	...
South of Kanhwára	...	...	?

It is, I think, tolerably safe to estimate the average thicknesses of the seams at—

	Ft.	In.
Top seam	2	6
Middle seam	2	0
Bottom seam	2	0

The area of the plateau west of Mohári being about two and a half square miles, there would be in the—

Top seam	19 million tons of ore.
Middle seam	15 „ „
Bottom seam	15 „ „

A large amount of ore from the top seam is available by open workings with free drainage in places where, as in some of the localities noticed above, it occurs at the very top of the escarpment with little or no overburden. A considerable quantity could also be got from the bottom seam, in the same way, in places where it extends into the plain at the foot of the slope. The great mass of ore from the two lower seams, however, and some probably from the top one, could only be obtained by mining. But mining in horizontal strata at such insignificant depths would be of the simplest kind, an immense quantity of ore being within reach by adits driven in from the face of the escarpment.

In the above estimate no account has been taken of the Kanhwára hills east of Mohári, where there can be little doubt ore exists in equal abundance.

Ordinary laterite as ore.

A considerable proportion of the ordinary laterite contains a high percentage of iron, and in countries less favoured than that under discussion would be looked on as a valuable ore. As a case in point, I may mention the hillock near Kailwára previously alluded to. It is about 40 feet high, and formed of rock laterite of a common type. A carefully chosen average sample yielded—

Ferric oxide	63·27 = Iron 44·29
Loss on ignition	10·48
Ignited insoluble residue	19·36
Undetermined (mainly alumina and lime) .	6·89
	100·00

Scope of notes.

I ought not to conclude these notes on the iron ores of Jabalpur without saying that they do not profess to give an account of every locality in which such mineral resources are to be found. Iron is, indeed, well known to occur in places which I have not visited—at Gangai, for instance, near the marble rocks, and the Majhauli hills, west of Sehora. Such ores, however, are, from their position, obviously out of count in connection with the Umeria coal. In the localities I have described, there is a practically unlimited supply of high-class brown, red, and manganiferous ores, none of which are more than a few miles distant from the railway. So much being ascertained, it would be useless, at any rate until the question of working the ores takes a more definite form than at present, to spend time in the examination of the more remote and less important localities.

FLUXES.

Lower Vindhyan limestone.

The most important member of the Lower Vindhyan series, and that possessing the greatest constancy in the section, is a band of limestone some hundreds of feet in thickness. Constituting, as it does, nearly the highest subdivision of the series, and generally dipping towards the north at moderate angles, it occupies the lower portion of the Kymore escarpment (beneath the sandstones of the upper series), or a belt of country, of varying width, immediately to the south. In this position it extends from near Sasserám to Bijerághogarh, a distance of some 200 miles. In the neighbourhood of the latter town the outcrop is exceptionally wide, covering a breadth of more than 3 miles. A little west of Bijerághogarh, however, the alluvium begins to encroach, the limestone outcrop rapidly narrows, and near the village of Kachgaon finally disappears beneath the more recent deposits[1]. But it is practically certain that, although concealed, the limestone forms a continuous fringe, bordering the Upper Vindhyan rocks, from Kachgaon towards the south-west, and then eastwards again to Murwára. In the latter position there are numerous quarries sunk through the alluvium.

These excavations are in a line running north and south from just south of the town to the base of Murwára Hill Station. With one exception they appear to be all very nearly on one strike. The depth of overburden in the different

[1] The narrow band, colored blue on the map, to the westward of Kachgaon, is of shale, which occupies a position between the limestone and the Upper Vindhyan rocks above.

quarries varies from 10 to 25 feet, except in the most southern of the line, where it is less than 5. It consists of clay, with Lower Vindhyan shales and inferior shaly limestone, which overlie the band that is worked. The latter consists of grey limestone in beds of rather small thickness, averaging say 2 to 5 inches. A carefully chosen average sample gave—

Carbonate of lime	94·65
„ of magnesia (by diff.)	2·98
„ of iron	·58
Phosphoric acid	traces
Sulphuric acid	0·00
Sulphur	traces[1]
Ignited insoluble residue	1·79
	100·00

—a result which shows the stone to be eminently suitable as a flux.

The band of superior limestone (above and below which is inferior stone) is only some 10 feet thick, and as it dips (towards the west) at 15°—20°, it cannot be followed towards the deep for any distance, the overburden even at the outcrop being excessive. The amount of stone therefore obtainable from the present quarries is limited. The outcrop of the whole band of limestone, however (which, as I have said, is some hundreds of feet thick in the Son Valley), probably extends for a considerable distance eastwards of the quarries beneath the laterite and alluvium, and many other beds of good stone are probably concealed in that position (There is indeed one excavation, some 130 yards east of the others, which has struck limestone, but of an inferior kind.) It is very doubtful, however, whether the more recent deposits are not too thick to allow of such being worked, even if found. A well in Mr. Olpherts' compound, a few hundred yards east of the line of quarries, was sunk through 90 feet of clay without striking rock.

In the event, then, of iron works on a large scale being started at Murwára, I think it is not impossible that, sooner or later, the supply of limestone on the spot will fail. In this case search should be made a little south of where the railway passes through the Kymore hills (west of Ponchi). It is quite possible that the limestone is to be found there beneath a less depth of overburden than at Murwára, and a few shallow wells would be sufficient to settle whether it is or not. If not, perhaps the best plan would be to construct a tramway from Murwára to the limestone area west of Bijerághoghar, or to the latter town itself. Limestone is to be had there in unlimited quantity at the surface of the ground. The tramway, therefore, besides serving to bring in iron ore from the rich deposits of the Kanhwára hills, and flux for smelting purposes, could supply lime-works on any required scale with stone, probably at a cheaper rate than it can be had now at Murwára, as the expense of removing such a mass of overburden would be avoided. As the Murwára[2] lime is now exported as far even as Calcutta, a market would doubtless be found for a large supply, if deliverable at a sufficiently low rate. A certain amount of passenger and ordinary goods traffic would also, no doubt, be obtainable for such a tramway as a feeder of the East Indian Rail-

[1] ·004.

[2] Or Katni. Murwára is the name of the town, Katni that of the adjoining railway station.

way. As the country is nearly level, with only one stream of any size to cross, there would be no difficulty in construction.

Lameta limestone.

There is an unlimited supply of limestone to be obtained from the lameta beds. Besides the fact, however, that these rocks do not approach the railway anywhere north of Jabalpur, the stone is markedly inferior to that of Murwára. An average sample, taken from several heaps collected for burning near Jabalpur, contained 21·38 per cent. of residue insoluble in hydrochloric acid, the remainder being carbonate of lime, with trifling quantities of magnesia and iron.

Aluminous laterite.

A pisolitic variety of laterite, containing, besides iron, a large proportion of alumina, occurs abundantly in the hills south of Murwára. If an aluminous flux should be required for smelting some of the hematite ores, the rock in question might perhaps be found useful.

DOLOMITE.

The occurrence of manganiferous iron ore, available for the production of spiegeleisen, would probably lead to Bessemer steel-making being included in any scheme for utilising the Jabalpur ores. If the basic process were adopted, dolomite for lining the converters would be required. The rock occurs in great abundance in the district, and, although very unequal in quality, can be obtained, by a little selection, of great purity.

Marble rocks.

The well-known 'marble rocks,' which are situated about 2 miles from Mirganj station on the Great Indian Peninsular Railway (11 miles from Jabalpur and 68 from Murwára), are dolomitic throughout. The rock has a saccharine texture, and is mainly of a pure white colour, although here and there it has a grey, yellow, or pink tinge. The bedding, as a rule, is not very thick, and in places it is quite thin, the rock verging towards a dolomitic schist. The greater portion of the dolomite contains disseminated crystals of tremolite, and very often irregular strangulated layers of quartz parallel to the bedding. But rock free from visible impurity is to be obtained without any difficulty. A sample of such, of a pure white colour, and obtained from different spots, yielded—

Carbonate of lime	55·48
" " magnesia (by diff.)	43·55
" " iron	·36
Ignited insoluble residue	·61
	100·00

This is a very close approximation to normal dolomite, which contains 54·35 and 45·65 per cent. of carbonate of lime and magnesia respectively.

Near Sleemanabad.

Dolomite of a somewhat less pure variety also occurs largely in the neighbourhood of Sleemanabad. It is mostly grey, with occasional cherty and quartzose bands, but rock free from visible impurity can easily be got by selection. A sample taken from the side of the railway between Dharoli and Deori (2 miles from Sleemanabad station and 20 from Murwára) gave—

Carbonate of lime	52·45
„ „ magnesia (by diff.)	38·22
„ „ iron	2·76
Ignited insoluble residue	6·57
	100·00

The same band of rock is also found close to the Sleemanabad station.

FIRECLAY.

Jabalpur.

Firebricks have been made in the Jabalpur jail from clay obtained from the Upper Gondwána beds, in the neighbourhood of Jackson's hotel. Last year I made some trial of their infusibility on a small scale. Three sharp-edged fragments, together with three similar fragments of a Scotch firebrick, from Kilmarnock, were placed in a covered crucible, and exposed for an hour to a dazzling white heat in a Fletcher's injector gas furnace. After cooling it was found that the edges of none of the fragments showed even incipient signs of fusion. The fragments of both bricks had acquired a slight glaze on the parts forming portions of the original surfaces, and when broken were found to have become extremely hard (so as to resist the point of a knife), somewhat porous, and the fracture semi-vitreous looking. The Jabalpur brick, before heating, had a smoother fracture than the Scotch one, and was much softer and more easily broken. After heating, however, both seemed to be equally hard.

Amdari.

Bábu Hira Lál, of the Geological Survey, recently forwarded some clay, similar in appearance to that from which the Jabalpur bricks were made, which he found in the Upper Gondwána strata in the hill west of Amdari, a village 14 miles south-west of Chandia. He states that the clay occurs in considerable quantity. It is a white indurated kind, breaking with a semi-conchoidal fracture when dry. When powered moderately finely[1], it yielded a highly plastic mass with water. From this small bricks with sharp square edges were made, measuring $1\frac{1}{2}'' + \frac{1}{2}'' + \frac{1}{4}''$. Similar bricks were made from fireclay from Glenboig and Garnkirk (Scotland) and from Ránigan j. One of each was enclosed in a covered crucible, with one end resting on the bottom, and the other touching the side. After exposure for an hour to a dazzling white heat in an injector furnace[2], the edges of the Amdari brick were only slightly rounded, but the brick had softened sufficiently to allow it to bend somewhat, until partially supported by the side of the crucible. It had not contracted in a marked degree. The Glenboig and Garnkirk bricks remained with perfectly sharp edges and contracted very slightly; the former showed no trace of bending, while the latter was bent in a very slight degree. The Ránigan j brick had the edges completely rounded, and was reduced to a semi-fused condition.

[1] Sifted through a sieve of 88 holes to the linear inch.

[2] The temperature was sufficiently high to soften the cover of a crucible from the Battersea works, and allow it to sagg downwards.

Some of the powdered Amdari clay was subsequently washed by suspension in water, dried, repowdered and sifted, and made into bricks of the same kind, which were similarly heated. The edges were very slightly rounded, and the bricks bent somewhat from their own weight, but decidedly less than that made from unwashed clay.

Although the clay, then, showed itself to be inferior to Scotch clay, good fire-bricks could probably be made from it, especially if washed. Similar clay is doubtless to be found elsewhere in the Upper Gondwána area, and one may expect the coal measures of Umeria to contain fireclays like those of Ránigani and other coal fields.

MURWÁRA AS A SITE FOR IRON-WORKS.

In the preceding remarks I have more than once alluded to Murwára as a site for future iron-works. The advantages of the position are not far to seek. The two primary conditions in selecting a site are firstly, that there shall be an ample supply of water, and secondly, that the spot shall be on the line of railway. Now, between Gosulpur, in the neighbourhood of the most important hematite and manganiferous deposits, and Umeria, *viâ* Murwára, the East Indian Railway and the projected line to Umeria only cross three streams of any size, namely, the Heran, south of Sehora; the Katni, at Murwára; and the Máhanaddi, near Chandia. The first of these is obviously too far away from the coal-field. The Máhanaddi is within a comparatively short distance of the coal, which forms the heaviest individual item of haulage, but not only would the ore and flux have to be taken from near, or beyond, Murwára to the Máhanaddi, but all the iron produced would have to be carried from the Máhanaddi to Murwára. Roughly speaking, there would be the haulage of ore + flux + iron *versus* the haulage of coal[1].

Murwára, as will have been seen, occupies a central position with reference to the different mineral products required. It is actually on limestone, and within less than 15 miles of an unlimited supply of the same mineral to the north-east. It is in the immediate neighbourhood of the lateritic brown ores, and about equally distant from the Umeria coal-field to the south-east, and the hematite and manganiferous ores to the south-west, while dolomite is to be had within 20 miles by railway. The Katni, which flows past Murwára, is a stream with a drainage area of 230 square miles above the town, and there is an abundant supply of water throughout the year[2].

[1] If the new line were continued to Belaspur a certain quantity of iron would find its way to the south-east, but the amount would probably be a small proportion of the total made.

[2] It appears from data kindly supplied to me by Mr. V. Pont, Resident Engineer of the East Indian Railway at Jabalpur, that in April last year, when the stream would be almost at its lowest, there was a flow of 996 cubic feet per minute.

A magnificent sheet of water could be formed by throwing a dam across the gorge, through which the Katni flows just west of Murwára, and a sufficient head of water perhaps obtained to work heavy machinery; to ascertain the exact fall obtainable would require actual levelling. The reservoir, however, could unfortunately only be made at the expense of submerging a large area of cultivated land.

On Lateritic *and other* Manganese Ore *occurring at* Gosulpur, Jabalpur District, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

In a previous volume of the Records[1] some account is given of the manganese ore at Gosulpur, which was visited by the Superintendent of the Geological Survey in 1879. The sections then available for examination were very poor indeed, but, judging from which could be seen, Mr. Medlicott thought that a large supply of the ore could probably be depended on. The following year a shaft was sunk with a view of testing the richness of the deposit. When this had reached a depth of 20 feet, the engineer in charge reported "that all trace of the ore was lost at a depth of 9 feet from the surface, at which depth a yellow subsoil, resembling ochre, was entered; that about 1½ cubic feet of ore were obtained, and even this small quantity of rather an inferior quality; that in consequence I recommended and discontinued operations." As this discouraging result was at variance with the hope previously entertained of a considerable supply, I was directed to take the opportunity, while in the neighbourhood recently, of visiting the locality and seeing how the discrepancy was to be explained.

The shaft is dug on the site of the pre-existing holes examined by Mr. Medlicott, from which the ore had been extracted for use in glass-making at Murwára and elsewhere. The section comprises—

	Feet.
a. Laterite	4 to 5.
b. Manganese ore	2 „ 2½.
c. Laterite containing some nodules of manganese ore, about . .	6
d. Distintegrated quartz schist dipping at a high angle (to bottom of shaft)	7

The manganese ore *b*, which, as mentioned in the previous notice[2], is pyrolusite mixed with some psilomelane, occurs in the form of irregular spongy nodules varying in size from a fraction of an inch to several inches diameter, and averaging perhaps half an inch to 1 or 2 inches. These seem to constitute an irregular layer, which is 2 feet thick, or rather more, at the shaft. It is exposed in two or three other places within a length of 20 feet. The level varies somewhat even in this short distance, and, as pointed out by Mr Medlicott, the ore found in the village well, 120 yards to the east, is at a lower level than that at the shaft. This difference is, I think, to be ascribed to the laterite (including the ore) having been deposited on an irregularly denuded floor of Bijáwar rocks.

There is little or no laterite of the ordinary (ferruginous) type included in the manganese stratum, and the separation between this stratum and the laterite above is tolerably well defined; that between the manganese and the laterite below is not so well marked, the laterite containing occasional nodules of pyrolusite through it. The laterite above and below the ore looks somewhat like the detrital variety, but experience elsewhere has led me to believe that the rock laterite[3] has a tendency to disintegrate into a mass of irregular nodular fragments, which bear

[1] Vol. XII, p. 99.

[2] *Ibid*, p. 100.

[3] By 'rock laterite' I mean the first form of laterite mentioned on page 117. The term is no doubt open to criticism, but is convenient and serves to avoid circumlocution.

a very close resemblance to the detrital form. Taking into account that no distinctly foreign matter is visible in the rock in question; that undoubted rock laterite occurs close by; and that the manganese ore is pyrolusite, not psilomelane (a point to which I shall allude again), I do not think there can be any reasonable doubt that the laterite, inclusive of the ore, is rock laterite, not detrital. Such is the view which Mr. Medlicott also took: "This laterite is of the older type; at least in the exposed sections I could not detect any palpable *debris*, which generally characterises the secondary or detrital laterite. It is therefore presumable that the lumps of ore are in *s*ite, and that the manganese is an integral component of the laterite in this position."[1]

With reference to the original source from which the manganese was derived, it is I think scarcely open to doubt that it is to be sought in the strong band of manganiferous micaceous iron which outcrops along the southern side of the Lora range and again at Gosalpur[2]. But, as I said in the preceding paper, the manganese in this ore occurs mainly, if not entirely, in the form of psilomelane, while the manganese of the laterite is mainly pyrolusite. The latter, therefore, cannot be the result of mere mechanical degradation and transport, unless it be supposed that the nodules in which the ore occurs are pebbles, originally of one mineral which has subsequently been changed into another. This mode of origin is rendered very unlikely by the absence of any other recognisable debris in the manganese stratum.

If the latter be not a mechanical deposit, it must be a chemical one. Carbonate of manganese being, like carbonate of iron, soluble in water holding carbonic acid in solution, the former metal is capable of being leached out and re-deposited in the same, or nearly the same, way as the latter[3]. During the deposition of the main stratum of manganese ore, the water appears to have held little but manganous carbonate in solution, while at the time the laterite below was formed, ferrous carbonate was the chief substance dissolved, but with some manganous salt, the manganese subsequently separating itself into nodules by segregatory action. Specimens may be obtained consisting in part of ordinary laterite, and partly of manganese oxide.

The occurrence of this manganese laterite, interbedded with ordinary ferruginous laterite, furnishes, I think, strong evidence in favour of the view as to the origin of the latter which I have advocated in a former paper[4], namely, that laterite is (in as far as the iron is concerned) a chemical deposit due to the leaching out and redeposition of iron through the agency of decaying vegetation and the carbonic acid produced by its decomposition. I of course am speaking of the first only of the three forms of laterite which I believe are now generally recognised, *viz*:—

1st.—Laterite due to deposition, and excluding the *3rd* form.

2nd.—Laterite due to the alteration of other rocks *in situ*[5].

[1] Vol. XII, page 99.
[2] Page 102.
[3] *Vide* Vol. XIV, page 145.
[4] *Ibid*, page 139.
[5] Some examples of this form are noticed in the preceding paper, pages 97, 98.

3rd.—Detrital laterite due to the denudation and redeposition of the *1st* or *2nd* form.

With reference to the amount of manganese ore obtainable, it is not easy to form any decided opinion. I think, however, that there is a fair chance of the layer being somewhat extensive, although very likely subject to much irregularity in level and the amount of overburden covering it, and perhaps in thickness also. When there is a demand for the mineral, the bed might be followed from the present diggings, and the superincumbent laterit utilised for road metal on the Deccan road which passes close by.

It will have been seen that the reason why so little ore was obtained from the shaft was that the latter passes through the manganese stratum into quartz schist below it. The shaft, indeed, merely exposed the thickness of the bed, but proved nothing as to its lateral extension.

In the preceding paper I have pointed out that a considerable quantity of psilomelane occurs with the manganiferous micaceous iron at Gosulpur. If the latter were worked in connection with iron-making, the psilomelane would be raised at the same time, and available as an ore of manganese. On assay it yielded 83·20 per cent. of available peroxide, or about the same amount as the lateritic pyrolusite. From both sources combined it may be reasonably hoped that a considerable supply of ore will be procurable when there is a demand for it.

Further notes on the Umaria Coal-field *(South Rewah Gondwana Basin), by* THEO. W. H. HUGHES, A.R.S.M., F.G.S., *Geological Survey of India.*

In my notes of last year on the Umaria coal-field were embodied the general results inferable from the evidence afforded by the preliminary experiments carried out under the management of the Rewah State: that coaly matter occurred in abundance; that it lay at a shallow depth from the surface over a proved area of 1½ square miles; that it thickened to the deep; that the gradient was low and advantageous for working; and that the quality of the coal at the outcrop was encouraging.

The promise was a fair one, and from the exceptionally commanding geographical position of the field it required small advocacy to show that if the expectations based on the introductory enquiries were confirmed, a splendid reserve of coal had been established. I am happy to say that Captain Barr, the Political Agent of Rewah, has keenly appreciated the exigencies of the case, and his further sanction has been obtained for carrying out such trials as shall set at rest any apprehensions that prudence may give rise to.

I confess that I have little or no misgiving as to the worth of the Umaria and the adjacent Johilla fields, and I have belief enough in my opinion to give it expression. But I admit the necessity of verification; and, in view of the important issues dependent upon the true practical estimate of these fields, I strongly commend the course that had been suggested of reducing to its narrowest limits the margin of uncertainty regarding the nature, quality, and permanency of their seams.

To achieve this object it was determined that the coal should be approached under the ordinary conditions of approved mining. There were two plans open for adoption, either to drive an incline from the outcrop, or to sink a shaft to the seam. The second method was preferred, as being in every sense more workman-like, and as affording more scope for efficiently dealing with an influx of water; and on the 11th March 1883, a pit of 10 feet internal diameter was commenced under the charge of Mr. Thomas Forster, M.E.

Shaft determined upon.

The position of the pit is near No. 8 bore-hole, where Mr. Stewart struck coal at 93 feet from the surface and recorded the thickness of the seam as 10 feet. I had a strong wish to go further to the deep towards No. 9 bore-hole, but I was deterred by the dread of water, and the possibly heavy outlay that would have to be incurred for pumping machinery.

Position of pit. Record of No. 8 bore-hole.

In an untried field it is always impossible to gauge the water difficulty, and I selected the spot for the trial shaft where I anticipated the least amount of inconvenience on this score. The choice has been up to the present justified by the results, for though the shaft is 40 feet deep one workman occasionally bailing suffices to keep it dry. Should the pleasant expectation that this fact gives rise to be strengthened by further experience, I would certainly recommend another pit near No. 9 bore-hole being put down. In the future development of the field, it would act as a ventilation channel; and in the initiatory stage it would yield another point where the quality of the coal might be judged.

Water.

According to the journals of last year, two seams measuring respectively 10 feet and 6 feet were passed through in No. 9 boring, and I remember that the coal brought up in the sludger was very clean and bright. The section of the hole is as follows:—

No. 9 bore-hole.

No. 9 bore-hole—

1.	Black surface soil	1′ 0″
2.	Brown sandy soil	7′ 0″
3.	Brown sandstone	9′ 0″
4.	Red sandstone	30′ 0″
5.	Carbonaceous shaly sandstone	3′ 0″
6.	Carbonaceous sandstone	13′ 0″
7.	*Coal*	2′ 0″
8.	Carbonaceous shale	1′ 0″
9.	Carbonaceous shaly sandstone	3′ 0″
10.	*Coal*	10′ 0″
11.	Carbonaceous shaly sandstone	3′ 0″
12.	Carbonaceous shale	1′ 0″
13.	*Coal*	2′ 0″
14.	Carabonaceous shale	1′ 0″
15.	*Coal*	6′ 0″
	TOTAL	92′ 0″

As the trial shaft has not yet reached coal, I have not much to comment upon; but I would explain that a more favourable record of labour could have been shown had local skilled artizans been available, and had not vexatious delays occurred in procuring and transporting the mining plant, and in gathering together the necessary building materials. It has also been a misfortune that Mr. Forster was continuously indisposed, and that his illness at one time was so aggravated that he had to go to Jabalpur for European medical advice. Notwithstanding all these drawbacks, very fair progress has been made; and compared with the experience during the early days in the Wardha Valley coal-field, there is considerable room for congratulation.

The main operations are those in connection with the shaft and the workings that will be extended from it; but in order to gain some immediate information respecting the seam, and at the same time win a little coal for night fires, smiths fires, limestone burning and brick burning, a narrow 6-feet incline was driven down to the deep from the quarry made last year. It has been advanced a distance of 20 yards. Throughout that length the seam retains nearly the thickness that it has at the outcrop, and for comparison I give the sections that are seen at the extreme ends of the incline.

Incline 6' wide.

		Outcrop (1882)	Heading (1883).
(a)	Coal hard	6"	10"
(b)	Stony band	1"	1½"
(c)	Coal bright	6"	7"
(d)	" hard	7"	6"
(e)	" bright	6"	6"
(f)	" hard . . .	4"	1½"
(g)	Stone band	2"	½"
(h)	Coal hard	2' 0"	2' 0'
		4' 8"	4' 8½"

Mr. Forster says that the coal works easily, and that there is a thin band of soft shale under the bottom of the seam which will facilitate pricking, and so reduce very materially the amount of waste. The roof is an excellent one, and not a single stick of timber has been required to support it. This is a most favourable feature in the estimation of the seam, for when a roof is bad the expenditure under the heading of timber forms a considerable item. With respect to the quality, the bottom 2 feet and the bright coals are excellent; but the hard band lettered (*d*), and which varies in thickness, would have to be picked out, as it clinkers very easily. The addition to the cost of getting the coal that this picking would entail might be set down at quarter of an anna a ton.

Mr. Forster's opinion of the seam.

The operations are not sufficiently advanced yet to yield facts on which to base conclusive inferences; but I may venture to say that the aspect of affairs up to the present is *not* discouraging.

The amount so far expended on the works and establishment is Rs. 8,000, and a further sum of Rs. 10,000 has been allowed for the completion of the enquiry, including the raising of 500 tons of coal.

Expenditure.

At a small additional cost the Johilla valley seams can be tested, as the necessary machinery and other plant will be at hand, and trained men will be available. I would strongly urge that these seams be not overlooked, and a less elaborate method of procedure to that adopted in the Umaria field may be followed.

Johilla seams.

A period of six or seven months ought to be quite time enough in which to carry out the plans now in hand, and by the end of the next working season, I trust we shall be able to give practical answers to all practical questions.

UMARIA,
23*rd May* 1882.

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Coal from Kywaising, Henzada, Burma.

THE CHIEF COMMISSIONER, BURMA.

Auriferous quartz from various localities in the Nilgiri district, Madras.

R. BROUGH SMYTH.

Tinstone from Mt. Bischof, Tasmania.

W. G. OLPHERTS.

Heulandite from Dumbartonshire, and two concretions from the Permian limestone of Sunderland.

DR. G. WATT.

Red hematite, micaceous iron, and limonite from the Jabalpur district, with a bloom of iron smelted from each ore; also pyrolusite from Gosulpur.

W. G. OLPHERTS.

A slab of Bhanrer sandstone with dendritic markings, from near Satna, E. I. R.

G. PEDDIE.

Opal in a ferruginous matrix, from Queensland.

G. NEVILL.

ADDITIONS TO THE LIBRARY.

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Titles of Books. *Donors.*

ABICH HERRMANN.—Geologische Forschungen in den Kaukasischen Ländern. Theil II, with Atlas (1882), 4to. & fol., Wien.

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THE UNITED STATES GEOLOGICAL SURVEY.

April 16th, 1883.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1883. [August.

On the microscopic structure *of some* Dalhousie rocks—*By* Colonel C. A. McMahon, F.G.S. (*With two plates.*)[1]

The gneissose granite.

In order to avoid repetition it will be convenient to describe the following sample specimens of the Dalhousie granitic rocks together. An account of their macroscopical and lithological aspect has already been given in my paper on the geology of Dalhousie (*supra* Vol. XV, p. 34).

Specimens described.

No. 1. Porphyritic gneissose granite. Bakrota Upper Mall, Dalhousie.
" 2. Ditto from the same locality.
" 3. Fine-grained granite from the summit of Dainkund.
" 4. Granite from the same locality.
" 5. Another specimen from the same locality.
" 6. Gneissose granite on the road from the church to the brewery, south-west side of the Dalhousie ridge.
" 7. Porphyritic variety on the same road.
" 8. Another porphyritic specimen from the same locality.
" 9. Gneissose granite on the road from the church to the water-works, south-east side of the Dalhousie ridge.
" 10. Another specimen from the same locality.
" 11. Fine-grained granite near Chil on the Dalhousie and Chamba lower road.
" 12. White granite on the same road about two-thirds of the way to Chil.
" 13. Prophyritic variety with very fine-grained matrix, having a superficial resemblance to a felspar porphyry. Between Dalhousie and Chil, on lower road to Chamba.
" 14. A light-coloured gneissose granite from the same locality.
" 15. Gneissose granite in actual contact with the slates on the road to Bakloh (above the slate quarries), Dalhousie.

[1] It is due to Colonel McMahon to state that this paper has been in my hands since the 15th March, and was in type for the May number of the Records, but had to be deferred on account of delay in obtaining the heliogravure copper-plates. This was particularly unfortunate when there is so much discussion going on regarding gneissose granite.—H. B. Medlicott.

All the above specimens are rich in quartz, and, as is usually the case in granites, this mineral polarises with great brilliancy. The polysynthetic structure is extremely prominent, and is very characteristic of the quartz of these rocks.

Dr. Sorby[1] states that "the quartz of *thin foliated* gneiss and mica schist differs from that of granite in having a far less simple optic structure;" * * * "instead of the larger portions of quartz being made up of a few comparatively large crystals, they are frequently composed of very many closely dove-tailed together, as if formed *in situ*." On the following page he goes on to state: "I have been unable to detect anything that would serve to distinguish the quartz of *thick foliated* schists from that of true granite."

An attempt has been made at fig. 1, plate I, to depict the appearance of the quartz, as seen in slice No. I, in polarised light. The quartz is seen to be composed of a number of large crystals and of congeries of microscopic grains suggestive of the roe of a fish. The small grains polarise as brilliantly as the large ones, and they add greatly to the beauty of the slices under the polariscope.

The fish-roe grains for the most part divide large grains of quartz from each other, forming a brilliant setting to them; sometimes this setting is thick, as in my illustration, but at others it is limited to a single line of crystals. Cracks in felspars filled up with these micro-crystals are common, and occasionally irregular branches meander into the interior of large crystals of quartz.

Some specimens of granite collected by me on the Grimsel pass, Switzerland, contain exactly similar fish-roe grains intermixed with larger grains of quartz.

On the whole I do not see sufficient grounds for regarding this polysynthetic structure as affording evidence of the original clastic origin of the Dalhousie rocks. This structure, as seen in these rocks, seems to me rather to suggest that the large grains were the result of slow cooling; whilst the fish-roe micro-grains appear to indicate either a comparatively rapid ending of the process, or conditions of strain towards its termination.

The quartz in all the specimens contain liquid cavities with movable bubbles. They exist in prodigious numbers in some specimens, whilst in others they are sparse; in most, however, they are abundant. Air, or gas, cavities are also present.

There are apparently some stone cavities. These appear to have either deposited a second mineral on cooling, or to have caught up opacite or other similar substance in the act of crystallisation. Some of them appear to contain fixed bubbles. These enclosures, however, are so exceedingly minute that they cannot be satisfactorily determined with the highest powers applicable. Some microliths contain internal cavities, running with the length of the microliths for a portion of their length, which undoubtedly indicate shrinkage on cooling.

All the specimens, without exception, contain more or less triclinic felspar. In some it is rather abundant; in others sparse. It appears from its optical characters to be oligoclase.

Eight out of the 15 slices contain typical microcline, and in some of them it is abundant.

[1] Anniversary Address, Q. J. G. S., XXXVI, 48.

Zirkel at pp. 45, 47, of his Microscopical Petrology of the 40th Parallel, describes the occurrence of a fibrous orthoclase in granite. A similar felspar is very abundant in these rocks. It occurs in all but three of the specimens, the slices in which it is not present, namely, Nos. 3, 12, and 14, being those in which typical microcline is also absent. In every slice in which typical microcline occurs, the fibrous felspar is present. It also occurs in three slices in which the typical mineral is absent. The fibrous appearance is only observable in polarised light, and the felspar in which it occurs seems to me to be a form of microcline. In some an incipient cross hatching can be made out; whilst in one, at least, it is distinctly visible in parts of the fibrous structure.

Orthoclase is present in all the slices, though, if the fibrous felspar be included under the head of microcline, the latter mineral is more abundant than orthoclase. The triclinic felspar (oligoclase) is very subordinate to the orthoclase and microcline taken together.

Much of the felspar is very opaque and has a white glistening appearance in reflected light owing to the presence in it of a multitude of extremely minute gas or air cavities. Liquid cavities with movable bubbles also occur here and there in the felspar.

Some of the felspars are studded with numerous microliths of silvery mica, which occasionally, in polarised light, impart to the portion of the slice in the field of the microscope the appearance of graphic granite. Zirkel, in his work on the rocks of the 40th Parallel (p. 46), notes the occurrence of a similar structure in the granites of Nevada.

Many of the orthoclases and microclines contain the usual intergrowths of plagioclase and occasionally grains of quartz. Some of the microcline exhibits a tendency to inter-laminated structure resembling that of perthite, only it is finer grained and less pronounced. The intergrowth of felspar alluded to is quite distinct from the ordinary twinned structure.

All the specimens contain muscovite, and in all but three biotite is present. The muscovite polarises in delicate but brilliant colours, and some of it is twinned. Some of this mica contains inclusions in the line of basal cleavage of a substance that is absolutely opaque, and black, in transmitted light, and shines with a bright silvery lustre in reflected light.

Muscovite is present in all these slices, not only in good-sized plates and packets, but in a form for which I propose the name of crypto-crystalline mica. In this form no definite crystals can be made out, the leaflets, under polarised light, fade and melt into each other and exhibit no definite shape; whilst no signs of cleavage or lamination are visible.

In transmitted light the crypto-crystalline mica varies from a pale buff to a pale grey colour, and has a superficial resemblance to the base of some felsites and rhyolites. In a specimen in my collection, labelled "Banded felsite, Glencoe" (I did not myself collect the hand specimen from which the slice was made), I find a precisely similar structure present, along with quartz, and the ordinary felsitic base of felstones.

The felsitic matrix of felstones is believed to be an intimate mixture of quartz and orthoclase; and I suspect, from the appearance of some of my specimens, that the crypto-crystalline structure of the mica now described may be due to an admixture of quartz with the mica.

The crypto-crystalline mica passes imperceptibly into a condition that would require, strictly speaking, the use of the term micro-crystalline, but in the following pages I purpose calling it all crypto-crystalline mica.

This crypto-crystalline mica is present in all the slices. It traverses them in ropy masses; sometimes it is extremely attenuated and drawn out into thin strings; at other times it widens out into comparatively broad expanses. It frequently encloses, or leads up to, crystals of muscovite, and of quartz, and more rarely embraces other minerals. It meanders through some large crystals of felspar; whilst isolated patches of it are caught up in other felspar crystals. In both these last cases it represents, I apprehend, the residuum left after the separation of the constituents of the felspar.

All the slices contain magnetite grains and garnets, but in some of them both the garnets and the magnetite grains are very minute.

Six of the slices, namely, Nos. 3, 4, 7, 11, 12, and 13, contain schorl. It is in a rather fragmentary condition, and is much cracked, the cracks being filled with quartz. In some cases the fragments appear to have floated some little distance from each other.

No. 15, a specimen of the gneissose granite in actual contact with the slates above the slate quarries, is a very interesting and instructive slice, for it exhibits in a typical way what appear to me to be decided indications of fluxion structure consequent on traction. Both the biotite and the crypto-crystalline mica are drawn out into long strings in the direction of the flow. This structure is not confined to the larger bands, which can be discerned with the aid of a pocket lens, but even the microliths of muscovite in the quartz are seen, under the microscope, to point in the same direction, and to be drawn out into long trains or strings.

Even more characteristic are the gas cavities. Some of these are themselves elongated and drawn out in the direction of the flow, and they are arranged in lines pointing in the same direction. Some of the gas cavities have deposited granular matter on cooling.

There are also stone cavities, the longer axes of which point in the direction of the flow.

This slice seems to me to exhibit, as far as a granite can do so, as decided fluxion structure as that to be seen in rhyolites and obsidians.

An attempt, to give an idea of the appearance of this slice under the microscope, has been made at fig. 2, plate II, where the bands of crypto-crystalline mica and biotite are represented drawn out into strings.

The quartz, though hyaline in transmitted light, is seen between crossed nicols to consist almost entirely of the fish-roe grains, previously described, drawn out into lines in the direction of the flow. Possibly this structure may depend on strain.

A pseudo fluxion structure is doubtless to be seen in many gneissic rocks, but that above described can alone be attributed, I think, to the action of traction in a rock in motion reduced to a plastic condition by heat.

Another piece of evidence in favour of the conclusion that the fluxion structure observable in the slice under consideration is due to traction, is to be found in the crumpled appearance of some of biotites. I have sketched one in this slice at fig. 4, plate II; a single crystal, one-half of which has been folded over and bent back flat upon the other half. This biotite must, I apprehend, have been crumpled up and folded over on itself after crystallisation, but whilst the folia were still in a somewhat pliable condition. I cannot conceive of a contortion of the basal cleavage lines, to the extent represented in the sketch, being produced in any other way. A moderate curvature of the basal cleavage lines is not an uncommon feature in the mica of some rocks, and I can readily understand how this may have been produced, even in the case of mica formed in clastic rocks by an epigenital process; for such mica, *formed in situ* in the spaces between the fragments of clastic origin, might often be cramped at the time of formation, and its symmetry interfered with, from want of space for its perfect development; but I do not think a mica could, from this cause, be completely doubled up in the manner represented in the illustration.

The basal cleavage lines of the mica enclosed in the long ropy strings of crypto-crystalline mica are usually at a slight angle to the direction of the flow, as represented at fig. 5, plate II, the direction of the flow being east and west. The outer edge of these biotites is usually covered with dark fluffy matter.

The foliation of the slaty portion of No. 15 is parallel to the line of fluxion in the granite.

Rocks next the gneissose granite.

Considering how important a thorough knowledge of the Dalhousie rocks is in determining questions of local geology, I propose to give a brief separate description of each of the remaining slices.

No. 16.—Junction of an intrusive vein, 3 or 4 yards wide, and the slate into which it is intruded, close to the main mass of the gneissose granite on the road to Mamul, Dalhousie. The actual junction of the two rocks is seen both in the hand specimen and in the slice.

M.—This slice shows the junction of the two rocks perfectly. The granitic rock possesses the characteristics of some of those already described, being distinctly gneissoid, whilst foliation has been set up in the slate. The structure of the slate corresponds closely to No. 19, described further on.

The slate contains numerous crystals of schorl which do not extend into the granitic rock; whilst the latter contains many small garnets, a mineral not visible in the slate.

There are several points of difference to be noticed between the silvery mica of the granitic rock and that of the slate. The silvery mica of the granite is pure looking; is in large leaflets; its basal cleavage is very perfect; and the cleavage lines are close together; whilst twinning is not uncommon. The silvery mica in the slate, on the other hand, contains numerous inclusions indicating an imperfect separation between the several constituents of the slate; it is in small leaflets; its basal cleavage is imperfect; and the cleavage lines are sparse; whilst there are no indications of twinning.

The granitic rock gives several indications of fluxion structure. The crypto-crystalline mica forms long curving streams in the ground mass, meandering about as an Indian river in its sandy bed during the dry months. In some places these streams approach each other and join; at others they make wide sweeps and diverge considerably. The curves are sometimes gentle, but at others they are rather sharp and have a wide radius. Sometimes the streams are broad; at others they are split up into innumerable narrow meandering rivulets. The dark mica also forms ropy-looking masses drawn out in the line of flow.

An attempt to represent the general appearance of a portion of this slice has been made at fig. 1, plate II; whilst at fig. 2, plate I (*a*), an illustration is given of the crumpling of the silvery mica as seen in this slice.

In some cases the twinning planes of the plagioclase are bent out of the perpendicular. I have occasionally seen instances of this in lavas, though it is of rather rare occurrence; and it seems to indicate conditions of strain subsequent to the crystallization of the felspar before the mineral had become perfectly rigid on cooling.

Zirkel, at p. 28 of his work already quoted, mentions the presence of fluid cavities in the quartz enclosed in garnets; but the garnets themselves, in this slice, contain numerous fluid cavities with movable bubbles. The quartz of the granite itself contains fluid cavities about the same size as those in the garnets.

No. 17.—Argillaceous schist in actual contact with a thick vein of granitic rock within 3 or 4 yards of the main mass of the gneissose granite. Same locality as the last. It is an indurated rock with minute flecks of mica visible here and there.

M.—In transmitted light the ground mass appears to be homogeneous and colourless, but thin and minute flakes of a green mica are thickly disseminated through it. Patches of opaque ferriferous material are dappled about over the field; whilst the slice is here and there stained with ferruginous material, and dots of yellow and red ferrite are occasionally to be seen. Flakes of colourless mica are sparsely scattered about, and there are numerous small fragments of a bluish-brown tourmaline. Between crossed nicols the slice presents a dark base relieved by numerous patches of semi-luminous material presenting highly irregular outlines, and bright flecks of mica.

The slice contains some air bubbles, but no liquid cavities. Some of the schorl shows that this mineral has been subjected to heat, and that the air or liquid enclosures which they contained expanded and forced a way to the surface of the mineral before its complete consolidation. An illustration of this, taken from this slice, is given at fig. 7, plate II.

No. 18.—Argillaceous schist in actual contact with the main body of the gneissose granite. From the same locality.

M.—This slice closely resembles the last. There is comparatively little schorl, and it is in very minute prisms. The slice contains numerous dots of magnetite.

No. 19.—An argillaceous schist in contact with a granitic vein, 3 or 4 yards wide, close to the main body of the gneissose granite. From the same locality. This is a more distinctly foliated rock than the preceding two specimens.

M.—The ground-mass consists of quartz in minute grains. Inter-laminated with this are strings of a fibrous dark-green mica and strings of the crypto-crystalline mica which I have shown to be a characteristic of the gneissose granite. Muscovite is also very abundant in the slice, whilst crystals of schorl, many of them being very minute, are present in great numbers. It is of the type and colour of that found in the gneissose granite, and for the most part it lies in a zone corresponding to the plane of foliation, the crystals lying more or less at right angles to that plane. The schorl contains numerous enclosures and some empty cavities, the contents of which have apparently forced their way through the mineral to the surface in the manner already described. The slice contains grains of magnetite, opacite, and ferrite, and some minute crystals of garnet; also one crystal of triclinic felspar. There are no liquid cavities.

No. 20.—Slate from the quarry near the gneissose granite on the Mamul Road, Dalhousie

M.—Under the microscope this is seen to be distinctly foliated; quartz, in minute granules, alternating with a fibrous green mica that is but feebly dichroic. Some very minute and imperfectly formed prisms of tourmaline are scattered through the slice.

Light flocculent clouds of nebulous matter, opaque in transmitted, and yellowish-white in reflected light, are also abundant. A sketch of a portion of this slice is given at fig. 3, plate I.

No. 21.—A spotted schist within a few yards of the gneissose granite, Potrain Hill, Dalhousie. Viewed macroscopically this has a distinctly foliated aspect, and specks of muscovite are visible here and there.

M.—The ground mass consists of quartz in small granules of very varied and irregular shapes, interspersed with crypto-crystalline mica that meanders about in all directions.

In this ground-mass are embedded numerous crystals of muscovite, and of a dark well-laminated mica, brown in transmitted light. Some of the latter contain grains of quartz and of magnetite. Magnetite and rounded grains of opacite are rather abundant in this slice, which also contains numerous prisms and fragmentary pieces of schorl, of the same type as that in the gneissose granite. There are also numerous micro-crystals of garnet. There are no liquid cavities.

At fig. 3, plate II, I have given a representation of a portion of this slice, showing the way in which the crypto-crystalline mica and the hyaline quartz are intermixed. The dark portions, in the illustration are intended to represent the former, and the uncoloured portions the quartz.

No. 22.—A similar rock a little further away from the gneissose granite, on the same road. It is of more spotted appearance and granular texture than the last, having lost, in the hand specimen, all traces of foliation.

M.—This slice closely resembles the last and requires no separate description. The crypto-crystalline mica is very abundant. Some of the grains of magnetite are of good size.

No. 23.—A fine-grained silicious schist in contact with the gneissose granite on the cart-road, between the Mall and the Bull's Head Hotel, Sananotala.

M.—This is a distinctly foliated rock, and the description given of slice No. 19 exactly applies to this one. No liquid cavities are present.

No. 24.—A crystalline granular rock a few yards below No. 23, on the same road.

M.—This exactly resembles No. 22, and is evidently the same rock. The quartz contains no *liquid* cavities. Small rounded fragments of the crypto-crystalline mica are included in the quartz; whilst grains of quartz are in*cluded in all the other minerals.*

In many cases small colourless microliths are attached to rounded grains of opacite in a way to suggest, at first sight, that the opacite had on cooling given off a gas that had intruded into the adjoining matrix. Illustrations of these combinations are given at fig. 6, plate II (see upper and left-hand figures). A careful study of these groups, however, showed that they are simply due to the accidental conjunction of two different minerals. Such forms as that depicted on the right hand of this figure seem to show this conclusively. The occurrence of these conjunctions, however, is so common that it seems to indicate that the rock was reduced to a sufficiently viscid and plastic condition, to allow of microliths moving by molecular attraction some little distance, at any rate, towards each other. The whole appearance of the slice, and the small rounded dots of crypto-crystalline mica included in the quartz, all point in the same direction, and indicate a viscid condition. The slice, I may add, contains numerous small rounded cavities that are probably due to shrinkage on cooling.

No. 23.—Another fine-grained silicious schist a few yards further down on the same road.

M.—This presents much the same features as the last slice. The schorl is not so abundant, and for the most part is in small prisms. The dark mica is arranged more in strings, and the crypto-crystalline mica is relatively more abundant than the quartz. In this slice it is micro-crystalline rather than crypto-crystalline.

Nos. 26 & 27.—Other speckled varieties of the crystalline granular rock a few yards further down on the same road. They contain ma grains of iron-pyrites. Sp. G. 2, 74.

M.—The description given of Nos. 22 and 24 applies equally to these specimens. Schorl is abundant.

The peculiarity of these slices is that they contain a considerable amount of zircon, in irregularly shaped granules, intimately intermixed with grains of quartz. Much of the zircon is distinctly dichroic, changing from a white, or faint bluish-white, to a delicate tint of light red. It does not exhibit colours in polarised light owing to its strong double refraction.

This is the first time that I have met with zircon *in situ* in Himalayan rocks, but a sample of the gold-bearing sands of the Sutlej river, sent me by a friend, is full of well-formed crystals of this mineral.

The quartz contains what appear to be stone cavities with fixed bubbles, whilst others have either caught up and enclosed opacite when in a plastic condition or have deposited it on cooling.

Rocks between the gneissose granite and the first outcrop of gneiss.

The cart-road, from near its junction with the Mall, between Thera and Potrain, to near the Bull's Head Hotel, Sanánotála, runs a little below the junction of the gneissose granite and the schistose rocks. Near the Bull's Head Hotel, on the neck of the Sanánotála spur, the gneissose granite re-appears, having been brought down, apparently, by the flexion of the strata. The schistose rocks between the gneissose granite on the Mall and the outcrop on the cart-road, near the Bull's Head Hotel, have been described in the preceding pages. The rocks, now to be described, are a descending series which crop out on the cart-road between the gneissose granite, near the Bull's Head Hotel, and the mica schists at Banikhet.

No. 28.—A silicious schistose rock in contact with a vein of granitic rock cutting through the schists. Viewed macroscopically two sets of lines may be made out with a pocket lens on the cut and wetted face of the hand specimen, and in the thin slice; the lines cutting each other at an angle of about 40°.

M.—Viewed under the microscope one set of lines is seen to be due to partial foliation; that is to say, to be due to the development of a tendency on the part of the dark mica to segregate in more or less parallel lines. It is noticeable, however, that the laminæ of the mica are arranged parallel to the *second set of lines*, and not to the lines of dark mica. The mica has segregated into lines, but each flake of mica in the line is arranged with its longest axis at an angle of about 40° to its own line.

The second set of lines alluded to are due to the occurrence of lenticular masses of crypto-crystalline mica, the lines of which, though discontinuous, preserve a pretty constant course in one direction. Another point noticed is that these lines of crypto-crystalline mica contain rather numerous microliths of tourmaline, the prisms of which point, as the microliths in rhyolite and similar rocks, in the direction of the flow.

These facts appear to me to indicate that the rock was subjected to two different processes of contact metamorphism; one process—due to heat—resulting in foliation; whilst the second process was probably the injection of matter from the granitic rock, possibly in a gaseous or liquid condition, along lines that followed the original direction of lamination or of cleavage.

This observation, which was very unexpected, seems to have an important bearing on the point at issue. If the crypto-crystalline mica in the schistose rocks adjoining the gneissose granite is not a product of the original constituents of those rocks but has been derived from the granite, the existence of the crypto-crystalline mica in the gneissose granite affords no evidence of the metamorphic origin of the latter or of its affinity with the schists.

The general appearance of this slice is closely similar to those of the slates in contact with the gneissose granite already described. The ground-mass consists of granular quartz. A dark green fibrous mica is very abundant, but muscovite is comparatively sparse. Schorl, as usual, is present. There are no liquid cavities. Ferrite is abundant.

No. 29.—A silicious schist adjoining the gneissose granite.

M.—This is only a variety of the spotted schists already described, as for instance Nos. 21 and 22. The crypto-crystalline mica is rather abundant and swells out into large lake-like expansions. I have observed a few stone cavities in this slice, one with a fixed bubble, and two with deposits in them.

Nos. 30, 31, and 32.—Very fine-grained schists, in descending order.

M.—These may be described together. Under the microscope they approximately resemble the slaty rock, No. 17. The ground mass consists of microgranular quartz, in which a yellowish-green scaly mica is so abundantly disseminated as to nearly pervade the whole mass. In No. 31 it has segregated into spotty masses in which it varies in colour, in transmitted light, from a green to a rich greenish-orange colour. Some of the mica is fibrous, and is, I think, paragonite. The slices contain grains of magnetite and ferrite, and slice No. 31 contains, apparently, a little hæmatite. All contain the opaque whitish mineral described under No. 20 and micro-prisms of tourmaline. The magnetite is most abundant.

Nos. 33 and 34.—Earthy looking schistose rocks. No. 34 has a strong earthy smell, even without breathing on it.

M.—These exactly resemble 30—32 and need no separate description. No. 33 contains two minute garnets. In 34 magnetite in micro-grains is abundant. In both micro-prisms of tourmaline are plentiful.

Section below No. 4 Barrack, Ballun.

No. 35.—A fine-grained schistose rock approaching the slaty type. With a pocket lens it is seen to have a fine micaceous glaze on the splitting surface.

M.—Under the microscope the rock is seen to be made up of a mesh-work of fine fibres, or microliths, of mica, in a quartz base. Larger crystals of mica are dotted about in it here and there, and stringy agglomerations of the fibrous mica. The mica is decidedly dichroic, and each of the microliths polarises rather brilliantly. I think the species is probably paragonite.

The slice contains grains of ferrite, and I think very minute grains of magnetite; also the flocculent opaque matter previously described. In this slice its colour varies from yellowish to reddish. It is, I think, a product of the alteration of magnetite.

No. 36.—A very fine-grained, pale bluish-grey, micaceous schist. The micaceous element is much more prominent in this hand specimen than in the last.

M.—This rock is so similar to the last that a further description is unnecessary.

No. 37.—A very fine-grained silicious rock approaching the slate type.

M.—This rock is of the same type as the last two, and consists of a fibrous mica, probably paragonite, disseminated through a quartz base. It contains a long irregular-shaped, lake-like space filled with hyaline quartz that has evidently been formed *in situ*, the prisms of mica projecting into it along its outer edges. It contains some gas enclosures and a few, very few, liquid enclosures with bubbles.

No. 38.—A buff coloured, very fine-grained, friable schistose rock.

M.—The structure and material are seen to be the same as the last. The mica is of yellowish-green in transmitted light, and it evinces a tendency to segregation, forming spots of darker colour than the ground-mass. There are some good-sized bits of ferrite.

No. 39.—A pale greenish-grey argillaceous schist.

M.—In both 37 and 39 the lines of original lamination can be distinctly traced on the cut surface with a pocket lens. In this rock (No. 39) they have suffered some contortion. The lines of incipient foliation are at a high angle to the lines of lamination in all three specimens. The microscope shows that No. 39 is composed of the same constituents as the last few described. The slice contains some micro-prisms of tourmaline.

No. 40.—A very fine-grained micaceous schistose rock.

M.—This consists of a quartz base in which a yellowish-green scaly mica is profusely disseminated. It is doubtless of the same species as the preceding. The slice is dotted over with countless cubes and octahedrons of magnetite.

No. 41.—Blue micaceous slate above Surkhi-galli.

M.—This consists of an intimate admixture of quartz in micro-grains and a green mica in minute scales. An immense profusion of magnetite grains are dotted over the field, mostly in elongated irregular forms, the longer axes of which are turned in the same direction. There are numerous micro-prisms of tourmaline and very minute crystals of sphene, which require high powers to detect. In many cases the sphene and magnetite have adhered together.

No. 42.—A pale blue slate similar to the last.

M.—This is apparently a very similar rock to No. 41; but the micaceous element is more fibrous and colourless.

No. 43.—A pale french-grey coloured argillaceous schist from the same locality.

M.—An exactly similar rock to No. 41 except that the magnetite is absent and a little ferrite has taken its place. The micro-prisms of tourmaline and sphene are abundant. I observed a liquid cavity in the mica.

No. 44.—A fine-grained friable whitish mica schist.

M.—This consists principally of minute scales of a yellowish-green mica and some minutely granular quartz. There are numerous air bubbles. I have not detected any tourmaline. Minute crystals of sphene are abundant. Magnetite and ferrite are also present.

No. 45.—A white wafery schist with a silky gloss on the cleavage surfaces.

M.—A very similar rock to the last, only the scaly mica is very colourless. The grains of magnetite and ferrite are very sparse. Micro-crystals of tourmaline and sphene as in the last. There are a few minute garnets.

No. 46. A light-grey, fine-grained silicious schist.

M.—The appearance of this rock under the microscope is very different from those described from No. 30 downwards. Its affinities are with the spotted schists Nos. 19 and 23, the latter of which it much resembles. It may be described as a micro-gneiss, and it consists of lenticular grains (eyes) of quartz and triclinic felspar set in crypto-crystalline mica which flows in ropy masses round them. The quartz very largely predominates over the felspar; indeed, the latter is sparse. Large flakes of muscovite are present, but no biotite. There are some good-sized pieces of schorl of the type present in the granitic rocks.

also a few rounded grains of what appears to be sphene. I have not been able to detect any liquid cavities even with the use of very high powers.

No. 47.—Paragonite slate (?)—An extremely fine-grained, french-grey coloured mica schist of slaty appearance.

M.—This has, unfortunately, been sliced so thickly that little can be made out, but it does not appear to differ in any essential particular from No. 41. Pounded fragments examined under the microscope confirm this impression and show that the rock is principally composed of an almost colourless mica in scales and fibres, and countless elongated granules of magnetite. The mica appears to be paragonite. There are as usual microscopic prisms of tourmaline.

No. 48.—The pearly mica schist of Banikhet.

M.—This is closely similar to No. 44. It is principally composed of a scaly mica, varying in colour from white to pale green, with ferruginous yellow stains in spots here and there. There is an admixture of quartz in a finely granular condition. The beautiful pearly opalescence of the thin slice, seen in reflected light without the aid of a lens, appears to be due to the presence of myriads of air or gas bubbles with which this rock is crowded. There are countless elongated grains of magnetite; the usual micro-prisms of tourmaline are also present; also micro-crystals of sphene.

Conclusion.

The general conclusions at which I have arrived from the detailed study of the Dalhousie rocks are as follows:—Fifteen specimens of the gneissose granite from various parts of the Dalhousie ridge, exhibiting some typical varieties of structure when examined macroscopically, are seen, when examined with the aid of the microscope, to be mere varieties of the same rock. No essential difference of any kind can be detected between them. All of them contain orthoclase microcline, plagioclase, quartz, muscovite, magnetite, garnets, and liquid cavities containing movable bubbles. Six of the specimens contain schorl in some abundance, and all but three of the thin slices contain biotite. In all the quartz exhibits a polysynthetic structure very prominently, whilst all contain crypto-crystalline mica.

Some of the slices give unmistakable indications of having been reduced by hydro-thermal agencies to a plastic condition, and exhibit true fluxion structure. It is also important to note that the specimens which exhibit these characteristics most prominently are those which show, when viewed macroscopically, a pseudo-foliation, and have consequently a gneissose aspect.

The rocks are not true granites, but it does not follow from this fact that they are necessarily of metamorphic origin. Between the deep-seated roots of volcanos and the lavas that have actually flowed out at the surface of the earth's crust, there must of course be many gradations. The presence of the crypto-crystalline mica in the Dalhousie gneissose granite, that is to say, the presence of an imperfectly crystallised residuum, seems to indicate their affinity with the felspar porphyries. Indeed specimen No. 13 approximates in its macroscopical appearance very closely to a felspar porphyry.

Allport, in his paper "On the Metamorphic Rocks surrounding the Lands'-end

Mass of Granite," Q. J. G. S., XXXII, 407, shows that the mineralogical changes produced in clay slates by the intrusion of a mass of granite are chiefly the development in them of some of the minerals which constitute its own mass; that is to say, quartz, tourmaline, and three kinds of mica; occasionally tremolite, magnetite ("and andalusile ?"), and in some localities felspar. The structural changes produced in clay slates by contact metamorphism, according to Allport, are "(a), foliation more or less perfect, with every gradation from nearly straight parallel lines to the most complicated contortions; and (b), concretionary, showing a decided tendency to segregation of both quartz and mica, the result being a spotted schist."

A precisely similar influence appears to have been exercised by the gneissose granite on the slates in contact with it at Dalhousie. As to structure, we have seen that foliation has been produced and "spotted schists" have been formed; whilst schorl, garnet, dark mica, muscovite, and magnetite have been introduced or created out of the constituents of the slate.

As regards mineralogical changes, Allport noticed in the rocks described by him in the paper just quoted, that the strata near the granite were "far more highly silicated than those at a distance from it," and he expressed the opinion that "there can be no doubt that much of the quartz has been derived directly from the intruded rock."

In the case of the rocks under consideration, a study of slice No. 28 led me to the conclusion that the crypto-crystalline mica seen in the schists in contact with the granitoid rock, is due to the injection of matter from the granitic rock into the schists in a gaseous or liquid condition.

Two other points are to be noted: *first*, that though the gneissose granite is rich in felspar, only one small crystal of this mineral was found in the numerous slices of rocks in contact with the gneissose granite examined under the microscope; *secondly*, that though liquid cavities are most abundant in the quartz of the gneissose granite, they are entirely absent from the schists immediately in contact with it, and are almost entirely absent from the schistose rocks below them.

Professor A. Geikie, in a critique on a paper by Père Renard, of the Royal Museum, Brussels, on the crystalline schists of the French and Belgian Ardennes (Nature, December 7, 1882) which came to hand after I had finished my examination of the slices now described, comments on the absence of fluid cavities in the quartz of the Ardennes schists as follows:—"In subjecting to microscopic examination thin slices of some of these altered rocks, M. Renard noticed that the quartz granules, presumably of clastic origin, have lost the liquid inclusions so generally found in the quartz granules of old sedimentary strata. This fact (already observed by Sorby in the case of sandstone invaded by dolerite) seems to indicate that the sand-grains have not escaped the influence of the changes which have so profoundly affected the other constituents of the former sediment."

Dr. Sorby notices this effect of contact metamorphism in his Anniversary Address (Q. J. G. S., XXXVI, 1882):— "One point of interest is," he writes, "that although the grains of sand contain many cavities which no doubt, as usual, originally contained water, they have all lost it, as though it had been expelled by the heat of the igneous rock, in the same manner as it is easily expelled from unaltered quartz by a high artificial temperature."

That the absence of liquid cavities, in the schistose rocks in contact with the gneissose granite, is due to heat, is rendered highly probable by the fact noted in the foregoing papers (see notes on slices 17 and 19) that pieces of schorl retain internal evidence that the contents of enclosures in this mineral had expanded by heat and forced their way to the surface.

We have already seen that whilst the granitic rocks abound in felspar, the altered slates in contact with them have not developed that mineral. I have also given my reasons for believing that the gneissose granite was reduced by *hydro-thermal* action (evidenced by the great abundance of its liquid cavities) to a plastic condition; and that portions which present a decided gneissose aspect exhibit true fluxion structure.

We have also seen that the schists in contact with the gneissose granite exhibit the peculiarities usually developed in rocks by contact metamorphism, that is to say, minerals present in the granitic rock, schorl, biotite, muscovite, garnet, magnetite, and crypto-crystalline mica have been developed in them near their point of contact; whilst the water, which was presumably present in the quartz of the clastic rock, has been driven off by heat. These facts, it seems to me, render it improbable that the features presented by the Dalhousie rocks are the result of selective metamorphism applied to a conformable series of sedimentary rocks.

The slaty and schistose rocks between the gneissose granite and the outer band of gneiss, though very varied in macroscopic aspect, present little variation under the microscope. They consist of an admixture of quartz and mica. The quartz contains no liquid cavities. One exception to this only was noted in the case of clear quartz plugging what may have been a pre-existing cavity, and which was probably filled with foreign material from intrusive granitic masses in its vicinity.

The quartz in all the slices described has lost all trace of its original clastic origin, and the mica has certainly been formed *in situ*. The change in the shape and appearance of the quartz grains has doubtless been due to after-growth in the manner pointed out by Dr. Sorby (Ann. Address, Q. J. G. S. XXXVI, 62)

The mica is of a different species from the micas present in the gneissose granite, and much of it appears to be paragonite. Some of the lower beds, as for instance No. 47, are, I think, entitled to the name of paragonite slates.

The general character of the schists may be said to be more silicious towards the gneissose granite and more micaceous towards the first outcrop of gneiss.

As the outer band of gneiss is neared, sphene makes its appearance in micro wedges and crystals, and is rather abundant. Garnets are rare. On the other hand, zircon is present in the spotted schists next the gneissose granite, and garnets are not uncommon.

Very minute prisms of tourmaline, of bluish colour in transmitted light, are present more or less throughout the schistose beds; but schorl, of the type found in the gneissose granite, is confined to the rocks in immediate contact with it.

Schorl also re-appears in No. 46, but the whole aspect of that rock is suggestive of the near proximity and the contact action of granitic rocks.

The metamorphism of the slate series, as a whole, does not seem to require the aid of great heat to explain it, for the action of moderately heated water is sufficient to account for the formation of the hydro-micas, the minute prisms of tourmaline, and the addition of quartz to the pre-existing grains of that mineral. The gneissose granite on the other hand has undoubtedly been fused, whilst its action on the slaty series in immediate junction with it has been analogous to the contact action of eruptive granite.

In conclusion, whilst I am not able to affirm as the result of my investigations up to date, that any of the axial gneiss of the Dhuladhár range is true gneiss, I find that it presents the characteristics of an igneous rock. It has been in a fused condition; it shows fluxion structure; it invades the rocks immediately in contact with it; its structure and composition is uniform over wide areas; and it expands suddenly along the line of strike from a width of 250 feet to a width of 6½ miles. The facts, at present known, point to the conclusion that the gneissose granite is an intrusive rock and has been squeezed up through a faulted flexure along an axis of maximum strain.

In my paper on the Geology of Dalhousie (*Supra*, Vol. XV, p. 44) I wrote—"The granitoid gneiss is highly porphyritic, and is undistinguishable from, and doubtless is identical with, the 'central gneiss.'" As a result of the subsequent microscopical study of the Dalhousie rocks, I have dropped the term "granitoid gneiss" in my present paper, and have substituted gneissose granite for it; and it is for consideration whether the term "central gneiss," introduced by the lamented Dr. Stoliczka, and since used to denote the "granitoid gneiss" of the North-West Himalayas, should not be discontinued in future.

The terms "central gneiss" and "granitoid gneiss" insensibly suggest cambrian and pre-cambrian times; and their use is apt to create a prejudice in the mind of the student both as to the origin and the age of the rock, for the tendency of petrological inquiry in the present day is to predicate a great geological age for crystalline rocks in which the granitic structure is due to regional metamorphism. But if the conclusions at which I have arrived in this paper are sound, it follows that the gneissose granite of the Dhula Dhár is of eruptive origin, and instead of being an archæan, cambrian, or "converted" silurian rock, it is in reality of tertiary age, and was brought into its present position in the course of the throes that gave birth to the Himalayas.

I do not intend to draw the inference that all the granitoid, and still less that all the gneissose rocks of the North-West Himalayas are of eruptive origin,—that would be too sweeping a generalisation to make from the facts at present ascertained,—but I think the most natural conclusion to draw from the evidence before us, taken as a whole, is that the "central gneiss" and "granitoid gneiss" of Dalhousie is really an eruptive rock; that is to say, whether it has travelled a short distance, only, from its seat of extreme metamorphism, or whether it was more or less directly connected with volcanic or plutonic action, it was in actual motion in a fused or plastic condition and occupies now the position of an intruder in the silurian series. I think the balance of evidence is against the supposition that it was reduced into a fused condition *in situ*.

DESCRIPTION OF PLATES.

PLATE I.

Fig. 1. Gneissose granite, Dalhousie. This sketch, taken from slice No. 1, is intended to show the polysynthetic structure of portions of the quartz.

„ 2. A portion of slice No. 16, taken from a granite vein intruded into slate, Dalhousie; (*a*) shows the crumpling of mica due to traction. See also fig. 1, plate II.

„ 3. A portion of slice No. 20. Slate from the quarry near the gneissose granite, Dalhousie.

PLATE II.

Fig. 1. A portion of slice No. 16, taken from a granite vein intruded into slate. See also fig. 2, plate I.

„ 2. A portion of slice No. 15; gneissose granite in contact with slate, above the slate quarries, Dalhousie. This sketch represents the mode in which the crypto-crystalline mica and biotite are drawn out into strings.

„ 3. A portion of slice No. 21; spotted schist within a few yards of the gneissose granite; Dalhousie. The sketch shows the way the crypto-crystalline mica and hyaline quartz are intermixed.

„ 4. Sketch of a biotite crumpled up by traction, taken from slice No. 15, gneissose granite in actual contact with slate.

„ 5. Showing a common mode of occurrence of mica in connection with the ropy strings of crypto-crystalline mica.

„ 6. Showing the mode in which grains of opacite and microliths of an undetermined mineral adhere together.

„ 7. A crystal of schorl taken from slice 17, showing that air or liquid enclosures originally contained in it had subsequently expanded from heat and forced their way to the surface of the mineral before its final consolidation.

Fig 1 × 60

Fig 2 × 60

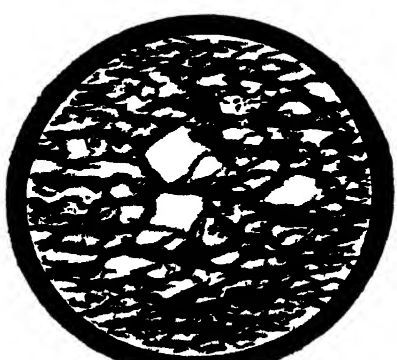

Fig 3 × 60

Reproduced in heliogravure from the original drawings at the Surveyor General's Office Calcutta.
May 1883

Fig. 4

Fig. 1×30

Fig

Fig. 3×30

Fig. 6

Fig. 7

Fig. 3×100

Reproduced in which sq... from the original drawing at the Surveyor General's Office, Calcutta
M... 1...

On the lavas *of* Aden—*By* COLONEL C. A. McMAHON, F.G.S.—(*With a plate.*)

A BRIEF account of the extinct volcano of Aden is given by Mr. F. R. Mallet, F.G.S., in his paper "On the Geological structure of the country near Aden, with reference to the practicability of sinking Artesian Wells." Vol. VII, Memoirs, Geological Survey of India.

The following description of the lavas found at Aden is taken from Mr. Mallet's paper: "The varieties of rock met with are very numerous; there are perfectly compact lavas of brown, grey, and dark-green tints, sometimes containing crystals of augite and not unfrequently those of sanidine, and there are rocks exhibiting every degree of vesicularity until we arrive at lavas resembling a coarse sponge and passing into scoriæ. The vesicles again are in some specimens globular, and in others flat and drawn out. In some places the lava is quite schistose, and might if seen *per se* be easily mistaken for a metamorphic rock. Such lava is sometimes vesicular, but by no means always so, at least not to the naked eye. Volcanic breccias are also met with, as near the main pass where fragments of dark-green lava are imbedded in a reddish matrix. Tufas are also present, but apparently to a limited extent. Some specimens of tufa shown me by Captain Mander, the Executive Engineer, were made up principally of fragments of pumice, from which it would appear that pumice must be amongst the volcanic products, though I am not aware of any locality in which it is found *in situ.* Obsidian is to be met with occasionally in thin seams."

I have not met with any detailed account of the micro-petrology of the Aden lavas, but the following passing allusions to them may be quoted here. Mr. Frank Rutley, F.G.S., in his Study of Rocks, p. 152, 2nd edition, writes as follows: "A globular condition of silica has been lately described by Michael Lévy as occurring in the euritic porphyries of Les Settons, and similar globular conditions of silica have been observed and noticed by M. Vélain in a quartz trachyte from Aden. The former author regards this condition as intermediate between the crystallized and the colloid forms of silica."

Professor A. Daubrée, in his paper on zeolitic and silicious incrustations (Q. J. G. S., XXXIV, 73), states that silicious infiltrations are found in many volcanic rocks of the "trachydoleritic class," and refers to Aden as one of his examples.

The above are the only references to the Aden rocks that I have yet met with, and the following account of some of the lavas to be found at that place may not be without interest. As I have never been able to remain at Aden for more than a few hours, my examination of the extinct crater has only been a cursory one. The specimens from the vicinity of the tanks were collected by me, but the others were collected for me by a resident Engineer through the kindness of a friend. I proceed to describe the specimens in detail.

Basalts.

No. 1.—A grey compact lava. With the aid of a pocket lens, crystals of felspar and numerous dots of a greenish-yellow amorphous mineral are visible here and there. The locality in Aden from which this specimen was obtained is unknown. Sp. G. 2·78. The rock is magnetic and under the blowpipe fuses to a black bead.

M.—The base consists of a devitrified glass in which dendritic and rod-like forms of magnetite are abundant. Magnetite is also present in regular crystallographic forms.

In this base countless prisms of felspar are starred about; whilst large porphyritic crystals of that mineral are visible here and there. The porphyritic crystals are all plagioclase with the exception of one medium-sized prism which is orthoclase. Many of the minute prisms are visibly triclinic and the others are presumably so. The porphyritic felspars contain numerous enclosures of the base.

There are several augite crystals in the slice, but they are not very fresh. Part of the magnetite has been converted into hæmatite or göthite, imparting a reddish tinge to the slice, when viewed in reflected light.

The greenish-yellow amorphous mineral, alluded to above, is probably a secondary product of the decomposition of olivine, but none of the unaltered mineral is to be detected.

This rock is evidently an ordinary basalt.

No. 2.—A very dark-grey lava from Station Flagstaff Hill. It is highly vesicular, the area of the vesicles in the thin slice being nearly equal to the substance of the lava itself, but they are too minute to be seen by the unaided eye.

The rock is decidedly magnetic and fuses readily to a black bead. It seems to be a favourite rock for building purposes, and it is said to take the chisel well.

M.—The ground-mass is perfectly opaque except at the edges of the vesicular spaces and at the ends of felspar crystals, where it is seen to be made up of microscopic globulites and grains of crystalline matter. Some of this globulitic granular matter appears to be augite.

The ground-mass contains numerous crystallites and small crystals of felspar, several of which are distinctly triclinic. They contain many enclosures of the base, and some are mere skeleton crystals. Some of the larger felspars enclose prisms of apatite.

Several augites are visible in the ground-mass.

This specimen is also, I think, a basalt.

No. 3.—A very dark-grey finely vesicular lava closely resembling the last. The rock is magnetic and it fuses under the blowpipe to a black bead. From Ras Baraldu.

M.—This so closely resembles the last that a separate description is not necessary. The vesicles are not so uniformly distributed as in the last specimen and merge into elongated confluent cavities. The thin slice in reflected light has a warm brown tint. The ground-mass is not so absolutely opaque as the last specimen. In the larger felspars the enclosures of the base are so abundant as to give them quite a skeleton appearance. A fragment of augite is present in the ground-mass.

This is said to be a good building-stone and to take the chisel well.

No. 4.—A dull red highly vesicular lava. It powerfully affects the magnet, and it fuses under the blowpipe to a very dark mass that adheres to the magnet. Locality from which obtained unknown.

M.—The ground-mass is quite opaque.

Andesites.

No. 5.—A slaggy-looking lava with crystals of felspar visible here and there. Some vesicular cavities contain a zeolite which also forms incrustations on the surface. The specimen was obtained near the Station Point Cemetery. Sp. G. 2·64. The determination of the specific gravity may be a little under the mark, as there are a few vesicular cavities. The specimen is powerfully magnetic, and it fuses at the edges.

M.—The ground-mass is nearly opaque and consists of multitudes of grains of magnetite disseminated through a base of flocculent matter, probably a product of devitrification rather than of decomposition. None of the magnetite exhibits regular crystallographic forms, and part of it has been converted into hæmatite or göthite. The latter imparts a reddish and pseudo-felspathic appearance to much of the base when viewed macroscopically.

The ground-mass contains numerous micro-prisms of felspar, whilst felspars of large size are porphyritically embedded in it. The latter are nearly all visibly triclinic, and contain very numerous enclosures of the base, and buff coloured amorphous masses, that probably represent decomposed augites. Augites are not unfrequently caught up in large felspar crystals, as is the case, also, in slice No. 1. The felspar contains gas cavities and enclosures of ferrite.

No. 6.—A dark-grey vesicular lava from the vicinity of Station Point Cemetery. The hand specimen resembles the mudstone matrix of a conglomerate from which the pebbles have been extracted, the vesicular spaces having very smooth and regular surfaces as if they had enclosed hard substances. Sp. G. 2·61. The hand specimen is strongly magnetic and fuses easily under the blowpipe to a black bead which adheres to the magnet.

M.—A striking feature in this slice is the presence of numerous crystals of a red mineral which I have not been able to satisfactorily identify. It occurs in six and four-sided prisms, and in irregular shapes, and in fragment-like pieces. Some are in long and thin prisms, others in rather massive lumps. In transmitted light it is of rich orange red colour—yellowish orange when thin—deeper red when thick. When the polariser alone is revolved it absorbs light distinctly, but does not change colour. It very frequently contains enclosures of felspar, and in one instance the latter has conformed to the shape of the prism. These enclosures seem to indicate that the mineral is an original constituent of the rock and not a secondary product. The cleavage is irregular. The angle of the prism varies very much; some being nearly right angles, others being very obtuse. The average of the measurements of 17 prisms come to 103° 52′. In a few, not included in this average, adjacent faces intersected at an angle of 135°. The variation in the angle seems due to the mineral itself and not to oblique slicing.

Extinction coincides with the length of the prism and with the diagonal of the prismatic angles seen in cross section.

Between crossed nicols the mineral changes from dark to its natural colour in this slice, but in No. 16 it changes from dark to a rich crimson colour.

The prevalence of four-sided prisms is against the mineral being rubellite, or an allied species of tourmaline; its orange colour and transparency shuts out the idea of its being hæmatite, whilst the extinction shows that it is not a monoclinic pyroxene. In some respects it would do for brookite and the angles would agree fairly well with the Arkansas variety of that mineral, but I do not feel satisfied that it is brookite.

Can it be an ortho-rhombic pyroxene? the presence of which mineral in augite-andesites has recently been determined by Cross, Rosenbusch, and Teal. Its colour is not favourable to this supposition. Altogether the mineral is rather a puzzle to me at present.

The base of the rock under consideration consists of a slightly devitrified glass, of pale yellowish colour, in which are disseminated a micro-crystalline mixture of felspar, magnetite, and granular hornblende or augite. It is not dichroic and from the angle of extinction in some pieces of prismatic form I think it is augite.

Besides the micro-prisms of felspar, scattered in great abundance through the base, felspars in larger prisms are porphyritically imbedded in the ground-mass. They are nearly all visibly triclinic, as are some of the very small ones.

Considering the low specific gravity of the last two specimens, I think they must be classed as andesites. They are evidently transitional forms between the basalts and the trachytes of the Aden volcano.

Trachytes.

No. 7.—A grey compact lava with minute crystals of sanidine visible here and there. From the vicinity of the tanks. Sp. G. 2·66. The hand specimen is magnetic, but not strongly so. Under the blowpipe it fuses to a dark bead.

M.—The ground-mass consists of an intimate mixture of minute felspar prisms and irregular-shaped pieces of felspar: countless patches or granules of hornblende, and grains of magnetite and ferrite. In this are porphyritically imbedded large crystals of felspar; plagioclase and sanidine being almost equally abundant. Two of the latter present penetration twins, the others are twinned on the Carlsbad type.

The sanidine contains numerous enclosures of the ground-mass, and also stone or glass enclosures that have deposited mineral matter on cooling. Two of these are depicted at figs. 7 and 8.

The margin of many, and occasionally the whole of the sanidines in this, and in most of the slices about to be described, have a curious dusty appearance. Under high powers these felspars are seen to be full of imperfectly defined contorted fibrous particles of a doubly refracting mineral, and the dusty appearance seems to be due to the irregular intergrowth of either quartz, or another species of felspar. These enclosures do not interfere with twinning, and the latter shows that the mineral is sanidine and not nepheline.

In a portion of the slice the hornblende and magnetite are arranged in dendritic combinations.

The hornblende exhibits dichroism very strongly. One set of cleavage lines are occasionally to be seen, and the angle of extinction is characteristic of hornblende.

The slice contains a piece of the red mineral described under No. 6.

No. 8.—A grey compact rock with numerous crystals of sanidine imbedded in it. From the vicinity of the tanks. Sp. G. 2·63. The hand specimen is distinctly magnetic; under the blowpipe it fuses at the edges and adheres to the magnet.

M.—This specimen is more felspathic than the last, and the base in transmitted light is clearer. It consists of a micro-crystalline admixture of felspar, in which very numerous patches of a yellowish-green hornblende, and grains of magnetite, are freely scattered about. There are also a good many patches of hæmatite, or gothite, most of which are directly connected with magnetite grains.

There are two sizes of felspar crystals porphyritically imbedded in the ground-mass, namely, medium-sized and very large sized. Nearly the whole of the felspar of all sizes is orthoclase, but there are a few prisms of plagioclase. The larger prisms contain numerous rod-like belonites, some of which are fractured, which are doubtless imperfectly formed apatite crystals. In some cases opacite, or granular magnetite, has formed on these belonites, and sketches of three of them are given at figs. 11, 12, and 13. These combinations are particularly worth noting, because exactly similar forms are common in the gneissose granite of the North-West Himalayas, and in both cases they seem to afford evidence of the rocks which contain them having been reduced to a fused or plastic condition.

In fig. 13 the magnetite is seen to have formed on the belonite after the consolidation of the latter, and to have completely embraced it. In fig. 12 the magnetite has partially encircled the larger mineral in its arms, whilst in fig. 11 it has consolidated along its edge. In fig. 11 a cavity, running with the length of the belonite, is seen depicted at (*a*). It is probably due to shrinkage on cooling.

It is interesting to find bodies, such as those described, common to acid lavas and the gneissose granite of the Himalayas.

The felspars contain thousands of air or gas cavities.

An isotropic mineral is to be seen here and there; one of the crystals presents a six-sided outline—the sides being equal—whilst the others are in more rounded forms. It is doubtless garnet.

No. 9.—A grey compact rock, somewhat mottled in appearance, with minute prisms of felspar visible here and there. The specimen was obtained near the tanks. Sp. G. 2·60. The rock attracts the magnet, and it fuses under the blowpipe to a dark bead.

M.—The ground-mass is dark owing to the abundance of magnetite; in other respects it does not differ from that of the slices of trachyte previously described. Amongst the large porphyritic crystals plagioclase preponderates over the sanidine, but the smaller crystals all belong to the latter species. Some of the triclinic felspar is in the form of long thin prisms.

The larger felspars contain numerous enclosures of the ground-mass. In some they are so abundant as to give the prisms a somewhat skeleton appearance.

Microliths and stone enclosures are abundant, whilst a zonal growth is visible in some of the sanidines.

There is one good-sized, rounded crystal and an irregular-shaped piece of augite, whilst numerous patches of hornblende are scattered throughout the ground-mass. The rounded augite encloses a minute crystal of hornblende. The latter mineral presents irregular shapes, but in one case the cross cleavage lines are fairly well developed.

The slice contains a garnet. Much of the magnetite has passed into hæmatite, or göthite, whilst an apparently hydrated species of iron oxide often stains the matrix round the magnetite grains.

The trachyte in this specimen appears to be approaching the andesites, and is on the border line between the two.

A sketch of a portion of this slice is given at fig. 2; a group of felspar crystals, round which much magnetite has collected, occupies the centre of the illustration. The felspars are seen to have caught up numerous fragments of the ground mass which are alligned in general correspondence with the cleavage planes of the enclosing felspars.

No. 10.—A compact light grey coloured rock with minute crystals of sanidine visible here and there. This was obtained near the tanks. Sp. G. 2·48. The hand specimen contains, caught up in the compact rock, several fragments of pumicious lava in which vesicular cavities are numerous. This seems sufficient to account for the abnormally low specific gravity, as the air caught up in the vesicular cavities of the pumicious fragments would be sufficient to vitiate the result. The hand specimen is magnetic, but it is almost infusible under the blowpipe.

M.—This seems to be quite a typical trachyte. The ground-mass appears to be made up of an aggregation of felspar microliths. In this are imbedded medium and large sized felspar crystals. Amongst the two latter sanidine is abundant and is in very typical forms. The slice contains very little plagioclase, and the felspar micro-prisms of the base are either undifferentiated or are orthoclase.

Hornblende occurs in patches throughout the ground mass, though it is not so abundant as in some of the slices previously described. There are one or two fragmentary looking pieces of augite. In transmitted light it is of a greenish-brown, or brownish-green, but of so pale a tint as to be almost colourless. It is not dichroic, and in extinction and other characteristics it agrees with augite. The outer edge is a good deal corroded, but internally it is perfectly fresh. Some of the hornblende is much corroded and altered. It is of yellowish-green colour, and most of it is decidedly dichroic.

The ground-mass contains numerous grains of magnetite. Hæmatite or göthite is present here and there, and has penetrated cracks in the sanidine; it also occurs in patches in the latter. Some apatite is also present.

A long cavity in the slice is stopped with calcite, which is here and there crystallized in characteristic forms. The calcite encloses some minute prisms of epidote. A zeolite appears to be also present.

Quartz trachytes.

No. 11.—A grey compact rock with minute crystals of sanidine visible here and there. Part of it is of dark grey, and part a very light grey colour; and when examined with the aid of a pocket lens, it has the appearance of two magmas imperfectly mixed together. The specimen was obtained near the tanks. Sp. G. 2·60. The rock is strongly magnetic. The dark portions fuse, under the blowpipe, to a dark magnetic bead, but the light portions fuse at the edges only to a transparent colourless glass.

M.—This is a very beautiful specimen in the field of the microscope. The ground-mass in transmitted light is, in parts, very clear and transparent, and in other parts, representing the dark portions previously alluded to, the magnetite and hornblende are crowded together, so as to almost cover an area equal to that occupied by the felspar. In the clearer portions of the ground-mass the magnetite and hornblende are in larger and in more perfectly crystallized grains. In the dark portions much of the hornblende is in an embryonic condition, being shapeless aggregations of minute granules, the optical characters of which are indistinct.

From the microscopic examination of this slice, I am disposed to think that the mottled character of the rock is due to segregation.

There are numerous large crystals of sanidine scattered through the ground-mass besides others of medium size. Plagioclase is sparse. The large felspar crystals contain numerous enclosures of hornblende and a profusion of stone enclosures. The curious dusty appearance seen along the border of sanidines, described under No. 7, is very prominent in those of this slice.

Patches of hæmatite or göthite are visible here and there, and some of it is distinctly traceable to the alteration of magnetite; whilst large grains of the latter have also stained the matrix for some distance round them with a yellowish doubly refractive substance.

The slice contains a garnet and a little apatite. Here and there patches of hornblende very much resemble leaflets of mica, but I do not think any of them are really that mineral, as they are of exactly the same tint as the undoubted hornblende contained in the slice, and no trace of cleavage is visible in any of the flakes alluded to. The slice, however, contains a thin string of crypto-crystalline mica meandering about in it, similar to that described in my paper on the gneissose granite of Dalhousie. This additional link connecting acid volcanic rocks with the gneissose granites of the North-West Himalayas is most interesting.

Free quartz is to be seen here and there in the ground-mass. It is evidently a residuum, and, like the quartz of granite, it is moulded on to the other minerals.

The slice also contains another specimen of the red mineral described under No. 6.

No. 12.—A pale grey compact rock with crystals of sanidine porphyritic in it, from the vicinity of the tanks. Sp. G. 2·57. The hand specimen is magnetic. Under the blowpipe portions fuse to a magnetic bead, whilst other portions are but slightly acted on.

M.—This specimen so closely resembles the last described that only a few additional remarks are needed. Plagioclase is subordinate to the orthoclase. Magnetite is plentiful and is in well-shaped grains. Hæmatite is also abundant and for the most part assumes dendritic forms, and is but feebly translucent.

Hornblende is very abundant, being present in both the ground-mass and in the felspar crystals; and some of the crystals present well-shaped six-sided prismatic sections.

Apatite is extremely abundant in the ground-mass, and the rock, when examined chemically, gives the phosphoric acid re-action with molybdate of ammonia very decidedly.

The slice contains two shapeless garnets.

Glass and stone cavities are very abundant in the felspar crystals, and are, for the most part, of types similar to figs. 4 and 5. Figs. 9, 10, and 16 are taken from this slice.

As in the last specimen, free quartz is present in the ground mass.

No. 13.—A mottled grey compact lava with felspar facets visible here and there. It was obtained near the tanks. Sp. G. 2·56. It is magnetic, and its behaviour under the blowpipe is as in Nos. 11 and 12.

M.—This specimen is so similar to the last that a detailed description is unnecessary. The ground-mass is not as clear as the two last slices; but the felspar crystals, on the other hand, do not contain hornblende, and they are much more free from enclosures generally.

Apatite is very sparse, and there are no garnets. Hæmatite is not so abundant, and it is not in dendritic forms.

The slice contains an augite with a deep dark border.

Numerous glass or stone enclosures are to be observed in the sanidine, illustrations of which are given at figs. 4 and 5. In some the matter deposited on cooling appears to be partly mineral and partly gaseous, as in figs. 6, 9, and 16; that is to say, a gas appears to have first separated from the glass, on the consolidation of the latter, and then on cooling to have deposited mineral matter previously held in suspension.

Numerous gas or air bubbles are present in the ground-mass.

Free quartz is present as in the last two specimens.

Fluxion structure is observable in a portion of the ground-mass, where the microliths of felspar are seen to flow round a large crystal.

A sketch of a portion of this slice is given at fig 1. It is not possible on the scale at which it is drawn to attempt to depict the microliths of the ground-mass.

No. 14.—A light grey compact rock with sharply defined patches of a dark lava visible here and there imparting a brecciated appearance to the hand specimen. This lava occurs near the tanks. Sp. G. 2·48. The rock attracts the magnet, but fragments of it are infusible before the blowpipe. Facets of felspar are visible in the dark and light portions alike.

M.—The ground-mass is clear owing to the comparative sparseness of magnetite. There are only two or three small pieces of hornblende present in the slice.

There is no plagioclase, but sanidine is very abundant, and, as usual, is present in very large, in medium, and in minute crystals.

Quartz is abundant and is a much more prominent feature in the ground-mass than in any of the specimens previously described. Over about half the total area of the slice, the quartz is intimately intermixed with the felspar of the ground-mass, and in polarised light the combination of the two present a curious sieve-like appearance, the quartz constituting the meshes. Here and there free quartz forms larger masses having an irregular ramifying external outline. Minute crystals of sanidine are frequently imbedded in the free quartz.

There are a few small garnets, whilst magnetite, ferrite, and hæmatite or göthite are present as usual.

No. 15.—A greenish-grey vesicular lava from behind the post office. The greater part of Steamer Point Church is said to be built of this rock. From a builder's point of view, it is said to weather badly. The hand specimen is feebly magnetic; and under the blowpipe it becomes glassy on the surface, but does not fuse to a bead.

M.—I have examined four slices of this interesting lava. The ground-mass is micro-aphanitic, and is composed of minute prisms of felspar radiating in all directions. Grains of quartz are visible here and there in the ground-mass, but they are most abundant along the margins of the vesicular cavities when they exhibit rounded and hexagonal outlines. It is I think, tridymite.

The quartz contains numerous liquid cavities with enclosed bubbles, a fair proportion of which are movable. The size of the bubbles, relative to that of the cavities containing them, varies so much that no reliable calculation can be based on the proportion between the two. One of the quartz grains contains glass enclosures that have deposited mineral matter on cooling, and one of them has several fixed bubbles. The ground-mass contains many air or gas bubbles.

There are no porphyritic crystals of felspar.

Hornblende is very abundant; most of it is in acicular prisms of irregular outline, and rather pale green colour, resembling the hornblende of the Wolf rock (phonolite) of Cornwall; but there are larger stumpy prisms, here and there, of bluish to dark green colour in transmitted light, that have sharp outlines, give good six-sided sections and occasionally exhibit cross prismatic cleavage lines. It is decidedly dichroic changing from brown to bluish-brown; but under crossed nicols the absorption is so powerful that the colours exhibited are very feeble.

No. 16.—A light grey vesicular lava from Flag Staff Hill. Sanidine and quartz are to be observed here and there. It is slightly magnetic and fuses at the edges. Numerous round silicious granules with rough surfaces are visible in the vesicular cavities; they are dull and somewhat opalescent-looking, and have none of the liquid lustre of vitreous quartz. Most of them are globular, but some are flattened and present hexagonal outlines and are seen to have a yellowish nucleus. They are infusible under the blowpipe, and hydrochloric acid takes no notice of them.

M.—Under the microscope these spherulitic bodies are seen not to be exclusively confined to the edges of the vesicular cavities, but to occur occasionally in the ground-mass itself. Their central portions are, in transmitted light, of buff colour, and are feebly translucent, but the outer portions are transparent. Most of the globular bodies have rounded outlines, but others are flattened at the poles and present a hexagonal prism in section. Those which occur along the edges of vesicular cavities are segments of circles, the yellow nucleus being truncated and abutting directly on the edge of the ground-mass. Under crossed nicols the transparent portion is seen to have a distinctly radiated structure, and in some a dark cross is visible. They polarise in simple black and white and never exhibit colours. In some, the rough exterior surface, alluded to in my remarks on the macroscopic aspect of the rock, appears to result from minute prisms, or minute plates of tridymite projecting from the outer surface. In both cases the angles of adjoining faces are approximately 120°.

These globular bodies seen in section resemble the spherulites of rhyolites, dacites, and acid vitreous rocks, and were those found in the ground mass, seen by themselves they would undoubtedly be taken for ordinary spherulites; but the way they stand out from the surface of the vesicular cavities, their occasional hexagonal outline, and the fact that the yellow globular nuclei of those which line the vesicular cavities ar usually bisected by the bounding surface of the ground-mass, and are not continued into it, shows that they differ from ordinary spherulites. They have evidently been formed, in the great majority of cases, either by the exudition of silica from the base into the vesicular cavities, or have been deposited in these cavities through the agency of steam or water; and are not, like ordinary spherulites, the product of the devitrification of the glassy base.

I presume that these globules are identical with those noticed by M. Vélain (see *ante*). Their behaviour under crossed nicols is not, however, similar to M. Michael Lévy's description of the globular silica occurring in the euritic porphyries of Les Settons.

It is not quite clear what Michael Lévy means by a "condition *intermediate* between the crystallized and the colloid forms of silica." It seems to me that the globular silica of the Aden lavas is only a variety of hyalite, and that its peculiarities are principally due to an intergrowth, or rather to a successive formation of hyalite and tridymite. The nuclei are probably formed of common opal.

The ground-mass of the rock under consideration is micro-aphanitic, and consists, as in many of the previous specimens, of light clear portions and dark portions, as though two magmas had imperfectly mixed together.

Some large porphyritic crystals of felspar are triclinic. Some of the felspars contain large enclosures of the ground mass which have not entirely separated from the main mass; whilst the dusty appearance described in the previous pages is very prominent in the felspars of this slice. In some cases it makes them resemble nepheline, but the angle of extinction and the twinning of the sanidine and plagioclase (for the dusty appearance is seen in both classes of felspars) usually prevent any mistake in their identification.

The ground-mass contains granules of greenish hornblende, whilst minute four and six-sided well-shaped prisms of a brownish hornblende project from the ground-mass into the vesicular cavities The prism of one measured exactly 124°, 30 [1]

Apatite is present, also magnetite and hæmatite or göthite. There are also several large and small crystals of the orange red mineral, previously described. Between crossed nicols it changes from a rich crimson colour to dark.

Several of the vesicular cavities are stopped with calcite

No. 17.—A greenish-grey fine-grained but highly vesicular lava, from the vicinity of the Station Point Cemetery. It is distinctly magnetic and fuses at the edges under the blowpipe. The siliceous globules are abundant.

M.—This is more uniformly vesicular than the last specimen, and the vesicular spaces occupy a considerable area relative to the ground-mass; consequently very large crytals of felspar are wanting and medium-sized ones are comparatively rare. In other respects this specimen closely resembles the last.

There are siliceous globules, as in the last, but tridymite is also abundant and occurs on the edges of the vesicular cavities. An overlapping of the plates is an almost constant feature in the tridymite of this and other slices. The vesicular cavities are occasionally plugged with a fibrous zeolite.

The red mineral is absent and the brown hornblende, of the last specimen, is extremely sparse. Green hornblende in acicular prisms is very abundant.

Trachytic Pitchstones.

No. 18.—A compact brick-red lava with facets of felspar visible here and there. From the vicinity of the Station Point Cemetery. Sp. G. 2·40. The rock is magnetic and fuses, but not very readily, to a white blebby mass full of air bubbles.

M.—The ground-mass is of such microscopic fineness that it requires powers of over 100 diameters to make it out. It consists of a matted mass of felspar microliths and fine granular matter. In this are scattered felspar crystals of various sizes, some hornblende and large magnetite grains. None of the felspars give evidence of being triclinic. The large felspar crystals contain numerous enclosures of the base. The slice contains countless crystallites of felspar that closely resemble those described in my paper on the basalts of Bombay,[2] having either frayed ends, or being mere skeletons enclosing the granular matter of the ground-mass.

Hyalites are to be seen in a few vesicular cavities; their outlines are semicircular.

This vitreous lava may, I think, be described as a devitrified trachytic pitchstone. A sketch of a portion of this slice is given at fig 3.

No. 19.—A reddish compact rock from the vicinity of the Station Point Cemetery. Sp. G. 2·38. This looks more like a rotten schist than a lava. Though not visibly porous or vesicular, yet when plunged into water it gives off a stream of minute air bubbles that lasts for some hours. It is not magnetic. Under the blowpipe it fuses with difficulty and becomes frothy.

M.—The ground-mass consists of micro-crystals of felspar interspersed with

[1] Rutley's Study of Rocks, p. 152, 2nd Ed. [2] Records, Vol. XVI., p. 42.

micro-grains of quartz, and an amorphous opaque red ferrite. It is of much larger grain than the last specimen.

All the porphyritic crystals of felspar are sanidine. They contain stone and glass enclosures. One of the latter is depicted at fig. 14, and is seen to contain three fixed bubbles and three crystals. Fig. 15 represents a cavity within a glass enclosure; the outer glass enclosure containing a large fixed bubble and a small crystal. The inner cavity appears to contain a minute bubble. Enclosures that have deposited dusty matter on cooling; and glass enclosures, each of which contains a large fixed bubble, are not uncommon. The slice contains no hornblende.

This lava seems to be intermediate between a quartz-trachyte and a pitchstone, but must, I think, be classed as a devitrified trachytic pitchstone.

Pumice.

No. 20.—A light grey pumice obtained in the vicinity of the Station Point Church.

M.—The vesicular cavities are filled with calcite, a zeolite, and I think some aragonite.

The pumicious part consists of a glass containing millions of air bubbles; some of these are round, whilst others are elongated, and are drawn out in the direction of the flow.

Conclusion.

Though I cannot suppose that my collection of the lavas of Aden afford complete examples of all the varieties to be obtained in the neighbourhood of that extinct volcano, still it is sufficient to show that the now silent craters, in the days of their activity, poured out basic, intermediate, and acid lavas. We have presented to us inside the main crater of Aden an unbroken succession of lavas, from acid pitchstones, on the one hand, to basaltic rocks on the other. Pitchstones shade into quartz-trachytes; quartz-trachytes into trachytes; whilst the latter pass into andesites, and through them, into basalts. On the whole, the acid rocks seem to have predominated.

Many of the lavas described in these pages have a mottled, and even a brecciated appearance, and it is difficult to say positively whether this is due to segregation, or to an imperfect blending of basic and acid magmas.

It would be interesting to know the order of succession in which the basic, intermediate, and acid lavas appeared; but on this point I have no information.

The specific gravity of each class of lava is low. I did not attempt to determine the specific gravity of the vesicular specimens, and though it is possible that hidden vesicles may, to some extent, have vitiated the determination of the specific gravity of some of those examined, yet, on the whole, I am disposed to attribute the low averages to the predominance of the acid element in the Aden lavas.

The following averages were obtained:—

Basalt	Sp. G.	2·78
Andesite	„	2·62
Trachyte	„	2·58
Quartz-Trachyte	„	2·55
Pitchstone	„	2·39

The pitchstones yield a somewhat abnormally high specific gravity, indicating their connection with the quartz-trachytes; but all the others, noted above, though within the minimum limits, are below the normal *average* specific gravity usually given for each class of rock in our text books.

The ground-mass of the intermediate and acid lavas, described in these pages, is micro-aphanitic; in no instance is it micro-felsitic. There are, except in the extremely vesicular specimens, and in the pitchstones, always three generations of felspar; micro-crystals in the ground mass, and medium and large-sized porphyritic crystals.

In the basalts and andesites the felspar is, almost without exception, plagioclase. Amongst the trachytes, those on the border line of the andesites, as No. 9, contain more porphyritic crystals of plagioclase than of sanidine; whilst those that approach the quartz-trachytes contain scarcely any plagioclase.

In intermediate varieties, as Nos. 8 and 10, the porphyritic crystals of triclinic and monoclinic felspar are pretty equal in number. In the quartz-trachytes, themselves, plagioclase is either wanting or is subordinate to the sanidine; whilst in the pitchstones plagioclase is wholly absent.

Augite is prominent in the basaltic lavas, but only stray crystals of it are present in the other lavas, namely, in Nos. 6, 9, 10, and 13.

Hornblende is abundant in the trachytes and in most of the quartz-trachytes; whilst it is sparse or wanting in the pitchstones.

Magnetite is present in all except No. 20, and every specimen, except Nos. 19 (pitchstone) and 20 (pumice), distinctly attracts the magnetic needle; some of them acting powerfully on it.

Hematite or göthite is found in all the specimens except the pumice; whilst apatite is commonly present, sparsely in some, but abundantly in others.

An isotropic mineral which I doubt not is garnet is to be seen in several slices, namely, in Nos. 8, 9, 12, and 14.

There is nothing in the appearance of the mineral to lead me to suppose that it is hauyne, a mineral frequently mentioned in connection with trachytes. Zirkel, in his Microscopic Petrology of the Fortieth Parallel, notes the occurrence of garnet in rhyolites and trachytes; and seeing that this mineral so commonly occurs in granite and syenite, its presence in the lava form of those rocks is hardly surprising.

Mica is conspicuous by its absence; but there is, however, a notable exception in slice No. 11 (quartz-trachyte), in which a thin string of crypto-crystalline mica, similar to that which takes so prominent a place in the gneissose granites of the North-West Himalayas,[1] is seen meandering through the slice. This link between acid volcanic and acid plutonic rocks seems to afford an indirect confirmation of the correctness of the conclusion regarding the affinities of the gneissose granite arrived at on other grounds.

Stone and glass enclosures are common in the felspars; also cases of magnetite forming upon and embracing microliths in a way that indicates a viscid, or

[1] Records, Volume XVI, p. 129.

fused, condition, and consequent freedom of molecular action,—facts which also form interesting points of contact with the gneissose granite of the Himalayas.

The general absence of fluid cavities is generally considered characteristic of the quartz of lavas, as compared with that of granite; but exceptions to this rule do not appear to be altogether uncommon. Dr. Sorby notes one in his Ann. Address, Q. J. G. S XIV. p. 84; another instance will be given in my forthcoming paper on the Traps of Dalhousie; whilst yet another will be found in this paper in my description of slice No. 15.

EXPLANATION OF THE ILLUSTRATIONS.

Fig. 1.—A quartz-trachyte, slice No. 13. The central felspar is imperfectly formed, and contains enclosures of the ground-mass.

Fig. 2.—A trachyte, slice No. 9; with a group of felspar crystals, in the centre of the field, round which magnetite and ferrite have collected. The felspars enclose portions of the ground-mass alligned in general correspondence with the direction of cleavage.

Fig. 3.—A devitrified trachytic pitchstone, slice No. 18.

Figs. 4 & 5.—Stone enclosures, slice No. 13.

Fig. 6.—Enclosures in felspar of slice No. 13. The matter deposited is partly mineral and partly gaseous.

Figs. 7 & 8.—Stone and glass enclosures that have deposited mineral matter on cooling.

Fig. 9.—A glass cavity taken from slice No. 12 which contains an enclosure of gas.

Fig. 10.—A stone enclosure, slice No. 12.

Figs. 11, 12, & 13.—Magnetite and opacite forming on belonites.

Fig. 14.—Glass enclosure, slice No. 19, containing crystals and fixed bubbles.

Fig. 15.—A glass cavity containing an inner enclosure, slice No. 19.

Fig. 16.—An enclosure taken from No. 12, which has deposited mineral matter and also contains gas.

Note on the Probable Occurrence *of* Siwalik Strata *in* China *and* Japan. *By* R. LYDEKKER, B.A., F.G.S., F.Z.S.

I have lately received from Herr L. v. Loczy, of the Royal Geological Survey of Hungary, a letter in which I am informed that during a recent expedition to China he observed extensive tertiary formations on the Upper Hwangho (Hoang-ho) river, in which he collected fresh-water shells and numerous bones of Proboscidia and Rodentia[1] (*sic*). In Western Kansu[2] he acquired from a native dispensary other large fossil bones, and the lower molar of an elephant which he considered very similar to the teeth of the Siwalik *Stegodon clifti*; this molar

[1] ? Ruminantia.

[2] A province on the Upper Hwangho, due north of Burma.

CORRIGENDA *and* ADDENDA *to* "SYNOPSIS *of the* FOSSIL VERTEBRATA *of* INDIA." *Supra, pp. 61—94.*

N. B.—It is to be regretted that Mr. Lydekker could not correct the proof sheets of his paper. Most of these corrections are such as only the author could make.—H. B. M.

Page 62, 86. The *Cochliodontidæ* (*Poecilodus* and *Psephodus*) should be referred to the *Ganoidei.*

" 63, line 8 from top, for *Oxychina* read *Oxyrhina:* the genus *Sphærodus* should be referred to the *Ganoidei.*

" 65 " 21 " bottom, for *barioccipital* read *basioccipital.*

" 66 " 4 " top, " *centre* read *centra.*

" 69 " 14 " bottom, before *British Museum,* add *Royal College of Surgeons and.*

" 70 " 3 " " for *two* read *three:* in the following line *dele* '*and a mandible.*'

" 71 " 1 " top, " *Enhydras* read *Enhydris.*

" 72, note, for *irvaticus* read *iravaticus.*

" 74, line 19 from top, for *H. hyopotamoides* read *A. hyopotamoides.*

" 76 " 11 " " " *acuticornis* read *porrecticornis.*

" 77 " 10 " " " *Nilgherries* read *Himalaya.*

" 80 " 2 " bottom, *dele* '*south.*'

" 81 " 3 " top, for *when* read *whose.*

" 85 " 1 " bottom, for *Eg.* read *Münst:* also on p. 87, line 12 from bottom.

" 86 " 4 " top, before *Sphyrænodus* add *Teleostei.*

" " " 5 " " below *Pycnodus,* add *Sphærodus rugulosus,* Eg.: this should also be inserted in the alphabetical list.

" 88 " 20 " " for *dhonkoka* read *dhongoka.*

" 92 " 17 " bottom, for *Typholodon* read *Typhlodon.*

" " " 8 " top, " *predicus* read *indicus.*

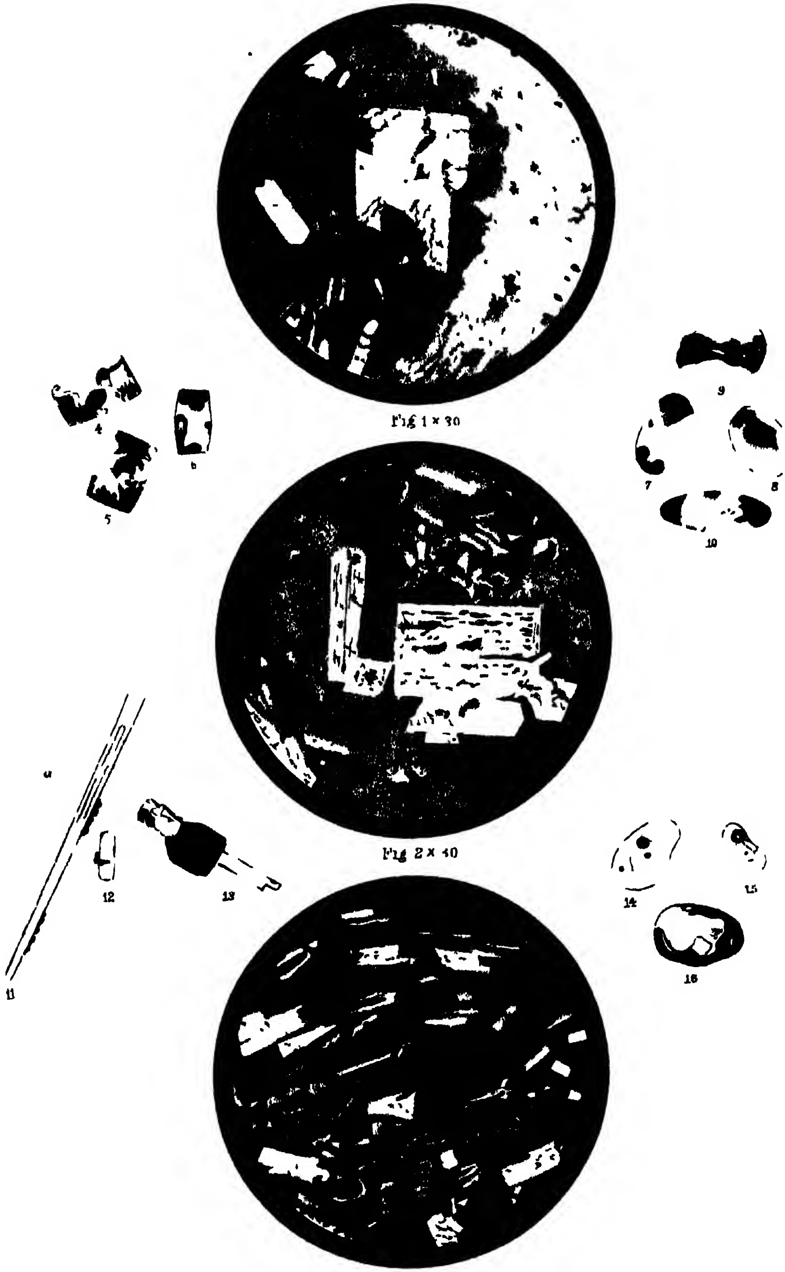

Fig 1 × 30

Fig 2 × 40

Fig 3 × 9

J Schaumburg, Lith[a]   Printed at Geol Survey Office

is described as being brown and highly mineralized, and apparently in very similar condition to the Siwalik fossils.

I am promised an opportunity of examining a cast of the molar, but the description given leaves little doubt that the strata whence the fossil was obtained correspond to the Siwaliks. It will be remembered that Professor Owen has described [1] the milk-molar of a *Stegodon*, said to have been obtained from "marly beds near Shanghai," which he referred to a new species under the name of *S. sinensis*, but which I have seen [2] no reason to separate from the Siwalik *S. clifti*. The mineralization of this specimen (now in the British Museum) is precisely similar to that of the Siwalik fossils and leads me to conclude that the beds from which it was obtained, together with the Hwangho beds, almost certainly correspond, at least in part, to the Siwaliks The geographical position of the Hwangho beds, due north of Burma, lends a strong support to this conclusion, as it is well known that the Siwaliks of that country, whence Crawfurd's original specimens were brought, extend far up the valley of the Irawadi, and thus are only separated by Yunan and Sechuen from the Kansu district.

In the same paper Professor Owen also described various other Chinese fossil mammals, belonging to the genera *Chalicotherium*, *Rhinoceros*, *Tapirus*, *Stegodon*, and *Hyæna*, and said to have been obtained from a cave in the province of Sechuen (Sze-chuen), or between Kansu and Yunan and Burma. The mineralization of these specimens is much less complete than that of the Shanghai and Siwalik fossils, but the difference in the manner of the entombment of the specimens is probably quite sufficient to account for this. The genera are all characteristic of the Siwaliks, and although Professor Owen has assigned all the specimens to distinct species, yet it has appeared to me [3] to be highly probable that the *Stegodon* is the same as one of the Siwalik forms; while work on which I am now engaged leads to the conclusion that the Sechuen hyæna is identical with, or very closely allied to, one of the Siwalik hyænas. Whether or no the species be the same, it appears to be most probable that the Sechuen mammals belong to the same period as those of the Siwaliks, and connect those of Burma with those of Kansu.

Turning to Japan, it may be observed that in 1881 Dr. Edmund Naumann figured and described [4] various remains of fossil elephants from that country, which he referred to the following species, *viz.*, *Stegodon clifti*, *S. insignis*, *Elephas namadicus*, and *E. primigenius;* the two first being Siwalik species, the second (or the allied *S. ganesa*) also ranging up into the Narbada beds, and the third being characteristic of the latter. These fossils indicate pretty conclusively that representatives of the mammaliferous beds of India, which probably correspond both to the Siwaliks and the Narbadas, exist in Japan, and are probably the continuation of the Chinese deposits.

[1] "Quar. Jour. Geol. Soc," Vol. XXVI, p 417.

[2] "Palæontologia Indica." Ser. X, Vol. I, "Siwalik and Narbada Proboscidia."

[3] *Ibid.*

[4] "Ueber japanische Elephanten der Vorzeit." 'Paläontographica,' Vol. XXVIII, pt. 1, pls. I—'II.

Since the publication of Dr. Naumann's memoir, another paper on the same subject has appeared by Herr D. Brauns,[1] which is certainly a very remarkable paper indeed. In that paper it is first of all attempted to prove that the Siwaliks are entirely of miocene, and the Narbadas of pliocene age, while the Japanese (and presumably the Chinese) mammaliferous deposits are all referred to the pleistocene. Now it is not my intention on the present occasion to go again into the question of the age of the Siwaliks and Narbadas, but there are two points in relation to Herr Brauns' treatment of this question, to which it is almost impossible to omit referring. It happens to be inconvenient to his line of argument that any of the Siwalik species should occur in the overlying Narbadas, and therefore, when such is stated to take place he adopts the very easy, but scarcely scientific, method of doubting the evidence. Thus in the case of the occurrence of *Stegodon insignis* (or the allied *S. ganesa*) in the Narbadas, it is stated[2] that the two specimens of broken teeth figured in the "Fauna Antiqua Sivalensis[3]" from those deposits are not sufficiently perfect for determination, and therefore that *S. insignis* does not exist in the Narbadas. Even if those specimens are insufficient evidence, if the author had but taken the trouble to refer to page 117 of the first volume of the "Palæontological Memoirs," he would have seen a very perfect specimen of the lower jaw of *S. insignis* (No. 1) from the Narbada described by Dr. Falconer; this specimen, which is now in the Indian Museum, where there are others from the same beds, leaves not the slightest doubt that *Stegodon insignis* (or *S. ganesa*, which, as far as teeth are concerned, is the same) occurs in the Narbadas. From this may be gathered the value of the following dogmatic statement of Herr Brauns, *viz.*,—

Elephas namadicus	solely pliocene,
Stegodon insignis	„ miocene.
„ clifti	„ „

In the case of the occurrence of the Narbada *Bubalus palæindicus* in the topmost Siwaliks, it is argued that the specimens are not properly determined. It happens, however, that they are unquestionably the same as the Narbada species. I have not figured them because there are so many other specimens of more importance. Similarly doubt is thrown upon the authenticity of the stone implements from the Narbadas. If this sort of reasoning be allowed, of course anything can be proved.

Leaving now the Narbadas and Siwaliks which Herr Brauns has proved to his own satisfaction are respectively pliocene and miocene and contain no species in common, attention may be re-directed to the Japanese fossils. Considering, as Herr Brauns does, that the beds from which these fossils were obtained are entirely pleistocene, and therefore altogether newer than the Siwaliks and the Narbadas, it would never do that any of the fossils from them should

[1] "Ueber japanische diluviale Säugethiere," Zeitś. d. Deutsch. Geol. Gesell., 1883, pp. 1—88.

[2] *Ibid*, p. 9.

[3] Pl. 56, figs. 10, 11.

be the same as those of either of the latter. Accordingly the fossils described and figured by Dr. Naumann are re-named as follows, *viz.*—

Elephas meridionalis, Nesti, = *Stegodon insignis*, Naumann, pls. 3-5.
Elephas antiquus, Falc. = *Elephas namadicus*, Naumann, pls. 6-7.
Stegodon sinensis, Owen = *Stegodon clifti*, Naumann pls. 1-2.

Now there is not the slightest shadow of a doubt that the specimens figured by Dr. Naumann under the name of *S. insignis* are true Stegodons, and belong either to the Siwalik *Stegodon insignis* or *S. bombifrons*; they have nothing whatever to do with a *Loxodon* like *E. meridionalis*. The molars of *E. antiquus*[1] and *E. namadicus* are so alike that it is difficult or impossible to distinguish them, and there is therefore at least a probability that Dr. Naumann's determination may be correct. The specimen figured by Dr. Naumann as *Stegodon clifti* is a typical specimen of the last lower molar of that species, like many in the Indian Museum. I can see not the slightest reason why this tooth should be associated with the Shanghai milk-molar of the so-called *Stegodon sinensis* and so separated specifically from *S. clifti* of the Siwaliks.

There accordingly seems not the slightest doubt but that Dr. Naumann is perfectly correct in referring two of the fossil Japanese elephants to Indian Siwalik species; while it is not impossible that a third is a Narbada form; a fourth species is, however, referred to the European and North American *Elephas primigenius*, and to this Herr Brauns adds the European *Bison priscus*, Bojanus.

These determinations lead to the conclusion that the mammaliferous beds of Japan in all probability correspond both with the Siwaliks and Narbadas of India (which may there be in normal sequence), with the former of which they are connected by the Shanghai, Kansu, Sechuen, and Burmese deposits; and that they also contain an admixture of European palæarctic forms, which have probably reached Japan through northern America. In place of the fauna of the Japanese beds being distinct from that of the mammaliferous beds of India and affording any argument for the latter being pliocene and miocene in place of pleistocene and pliocene, all the evidence points very strongly to the equivalency of the two, and to the confirmation of the latter view of their age.

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Note on the Occurrence of Mastodon angustidens *in* India. *By* R. LYDEKKER, B.A. *&c., &c.*

Several specimens of the "intermediate molars" of a trilophodont mastodon collected by Mr. W. T. Blanford in the lower Manchhars (Siwaliks) of the Dera Bhugti country (Eastern Baluchistan), are absolutely indistinguishable from the corresponding teeth in the British Museum of *Mastodon angustidens*, Cuvier, of the upper miocene of Europe.

The occurrence of a European species of mastodon on the extreme western

[1] I am indebted to Herr Brauns for pointing out that in "Siwalik and Narbada Proboscidia" I have inadvertently given the age of *Elephas antiquus* as pliocene instead of pleistocene.

limits of India is a fact of great importance, indicating that we may look for a commingling of the faunas of the Siwaliks, and of the European upper miocene and lower pliocene in Persia and Asia Minor.

These important and interesting specimens will be figured in the "Palæontologia Indica" at no very distant date.

Notes on a Traverse between Almora *and* Mussooree *made in October 1882 by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

The following notes were made on a rapid tour between Almora and Mussooree during the month of October last; they cannot of course pretend to be a detailed description, but are of some interest in view of the question of the continuity of the Himalayan rocks in the Almora and Simla regions.

At Almora the rocks are gneiss and schists of various descriptions, lying nearly horizontal on the east of the Kosi, but on the ascent to Bainskhet the dip increases to 45°, the direction being N. 10° E., a dip which continues steady in direction, though varying in amount, till the Gagas is reached. Here the road runs over alluvium for a couple of miles, but rock again shows up on the hill called Buridunga; it is a porphyritic gneiss, similar in structure to the central gneiss. As the road runs near the northern boundary of this exposure cutting across it in several places, it is seen to be fairly straight and presumably a fault, the schists in contact with the gneiss dipping south-south-east; at Dwarahat, where the road cuts across the exposure here not a mile broad, the dip of the foliation of the gneiss has bent round to south-west and, though I was not able to trace the gneiss further to the north-west, I have no doubt that it does extend along the ridge since in the streams flowing down to the Khurrogadh blocks of it are not of infrequent occurrence.

Along the road between Dwarahat and Ganain the only exposure of slates seen was below Naugaon on the south-west side of the valley where they dipped W. 30° S., while near Ganain the dip was south-west.

On the eastern side of this valley, the ridge is capped by limestone (krol), which, apparently forming the peak of Dunagiri, descends further north, at the village of Damtola, almost to the bottom of the valley, and is seen to extend northwards from Ganain as far as the eye can reach, being confined to the eastern side of the valley with the exception of two patches capping the spurs above Bushbira and Naugaon respectively. As is generally the case, no dip was accurately determinable in the limestones, but they evidently dip somewhere about north-west.

Beyond Ganain, where the road leaves the alluvium, slates come in with a dip to W. 10° N. and on the ascent become more and more schistose; the dip at the same time becoming flatter, till near Jaurasi the porphyritic gneiss again comes in with almost horizontal foliation; this is not improbably a continuation of the Dwarahat exposure.

The gneiss continues to near Bongdhar, the only interruption being below the Makroli hill, where a narrow strip of black crush rock is let down by faulting. Near Bongdhar the slates come in again, at first with a N. 50° E dip at 45°, but this soon bends round to the normal N. 10° E. dip, the schistose slates continuing beyond this with a dip varying between N. 10° E. and N. 30° E.; at the bridge over the Nyar a thin band of porphyritic gneiss, probably here merely a more metamorphosed band among the schists, is exposed; opposite Gwalkura quartzites overlie the slates and continue to the bridge between Chifalghat and Pauri. On the crest of the ridge crossed on the road to Pauri quartzose rocks come in again, while beyond this the slates are much disturbed, but keep a pretty steady E. 10° N. and W. 11° S. strike.

Beyond Srinagar there is not much of interest to note; the quartzites show up on the ridge below Maniknath which is itself capped by limestone, but for the most part the rocks are of a recognisable infra-krol type.

Beyond Tiri, where the road runs along the Mussooree ridge infra-krols, quartzites, limestone (krol) and in one place the Blaini are seen, but the structure, as is the case everywhere on the outer ridge, is far too complicated to be unravelled by a simple traverse along the strike of the rocks.

I have reserved for separate notice the alluvial deposits, of which I shall now mention the more important.

Between Bainskhet and Dwarahat near the village of Kapalna the road runs along the surface of an old lake deposit, of which a narrow strip has been left uneroded, the streams on either side having cut deep into the deposits; in both the other valleys crossed before reaching the Gagas traces of extensive deposits are seen but forming a mere skin on the rocks below, having been almost entirely removed by the streams. At Kapalna the gradual raising of the deposits has given the drainage an easier escape over a saddle in the watershed into the next valley to the west; hence the lower part of the deposit has been exposed to the erosion of its own drainage only, while in the other valleys the streams flowing down from the hills to the north have almost entirely washed away the alluvium.

In the Gagas valley there is another alluvial deposit, which, having come mostly from the hills to the west, has by its slope forced the river to the eastern margin of the plain, where it has now cut for itself a new channel in the solid rock of about 60 feet in depth.

This deposit extends up the Pokhy valley, and some of the drainage of its western extremity flows into the Chundas. Here again there has evidently been a diversion of the drainage, due to the gradual raising of the surface of the alluvium to the level of one of the saddles in the original watershed.

Near Dwarahat there is another broad expanse of lacustrine deposits situated at the head of the Baiaru river. These deposits which, be they lacustrine or no, are at any rate formed in true rock basins situated at the very heads of the drainage areas, and rising almost to the level of the watershed have never, so far as I am aware, been adequately explained. They are by no means of merely occasional occurrence, but are scattered throughout these hills; one very good example being at the head of the Blaini river near Solan on the Simla road.

The three rivers which meet at Ganain have all broad alluvial bottoms, part being close down to the present level of the streams, the rest forming a terrace raised some 30 to 60 feet, but the low level ground seems to be merely due to the erosion of the stream, and not to a more recent deposition.

Near Ganain is a very interesting lake known as the Turag Tal; it is situated at the head of one of the streams flowing down to Gunain. In the valley of this stream an alluvial flat extends right up to the foot of the barrier, which is most clearly a landslip, for not only is the gap in the hill from which it has descended most evident, but the only other possible explanation, *viz.*, a moraine, is at once barred by the absence of any other rock but limestone in the barrier which is composed entirely of fragments and not of rock *in situ*. Above the barrier is a broad alluvial surface, the lower end of which is covered by water probably not of any very great depth. The level of this alluvium is about 200 feet above that in the valley below the barrier which itself rises 50 feet above the upper alluvium; the total depth of the landslip is therefore 250 feet, and the time that has elapsed since its fall has been that required for the formation of alluvium 200 feet in thickness.

Near the head of the Binan river there is a small deposit of alluvium as also at Chopryon and Kandura near Powri.

At Srinuggar and Tiri there are extensive terraces covered with a thin coating of river gravel, but in the main merely carved out of the solid rock.

The above-mentioned alluvial deposits are all in true rock basins, but only the three first mentioned, *viz.*, those near Kapalna, in the Gagas, and at Dwarahat, seem, from their uniformity and fineness of texture, to be of lacustrine origin.

Though there was never much doubt as to the propriety of correlating the rocks on the Almora section with those of the Simla region, such shadow of it as there was may be held to be now dispelled, for in the region crossed between Almora and Mussooree the rocks are seen to become gradually less metamorphic, and the distinctions of the sub-divisions but obscurely seen near Almora become more and more marked till the rocks assume the normal character which they are found to maintain from Mussooree to the north-west.

Note on the Cretaceous coal-measures *at* Borsora *in the* Khasia Hills, *near* Laour *in* Sylhet, *by* TOM D. LA TOUCHE, B.A., *Geological Survey of India.*

I have visited and examined a section of the coal-bearing rocks situated at the foot of the Khasia Hills to the north of the district of Laour.

Position of the section.

The section examined occurs in a ravine, at the mouth of which stands the Garo village of Borsora, about 5 miles west of the point where the Panatibh or Jadukhata river leaves the hills. At the edge of the plains on either side of this village nummulitic limestone is exposed dipping to south-south-east or towards the plains at an angle of 38°.* On proceeding up the ravine along a path on the west side of the stream no sections of rock *in situ* are seen, but the path is covered with blocks of

* From this a large amount of stone has been quarried by Messrs. Inglis & Co.

a coarseish yellow and brown sandstone. The path rises for about half a mile until the mouth of a small steep ravine on the west is reached, in the sides of which the coal seams are exposed.

Description of the section.

At the junction of the two ravines carbonaceous shale is seen in the bed of the stream dipping to south-south-east at an angle of 12°. Upon this rests a seam of good coal 3 feet 10 inches thick extending for about 20 yards along the side of the ravine. This is overlaid by 5 feet of shaly sandstone, upon which rests a second seam of coal 3 feet 4 inches thick. This seam has been disturbed by several small faults or slips, and parts of it have been denuded to some extent before the deposition of the overlying sandstone, so that its thickness is not so constant as that of the lower seam. Proceeding up the ravine about 60 feet of fine yellow sandstones are passed over, and a third seam of coal is met with, cropping out on both sides of the ravine. The thickness of this seam could not be determined exactly, as a small landslip has occurred in the rocks above, and has partly covered it, but it is at least 4 feet thick, though not quite free from shaly partings. Above this the ground is covered for 50 or 60 feet with the debris from the slip above mentioned, consisting of fine yellow sandstones and shales with many fragments of coal, and above this again, at the top of the section, is a fourth seam, of shaly coal, 2 feet thick. In the whole section therefore of about 150 feet there are about 12 feet of good coal, distributed in three seams as shown below, in descending order:—

		Ft.	*Ins.*
Shaly coal	about	2	0
Fine yellow sandstone and shale	„	60	0
Coal seam, No. 3	„	4	0
Fine yellow sandstone	„	60	0
Coal seam, No. 2	„	3	4
Shaly sandstone	„	5	0
Coal seam, No. 1	„	3	10
Carbonaceous shale, thickness unknown.			
TOTAL	„	138	2

Quality of the coal.

The coal of seams Nos. 1 and 3 is much disintegrated by exposure, so that it is difficult to get good specimens for analysis, but it appears to be a very good coal, with a bright fracture and black colour, containing numerous specks and nests of a kind of fossil resin. This resinous substance, which is characteristic of the coals of this region occurring in cretaceous rocks, together with the position of the seams below the nummulitic limestone, shows that the coal is of the same age as that of the Garo hills and the small basin at Maobelarkar, and is therefore distinct from the coal of Cherra Poonjee, which occurs above the limestones. The coal of seam No. 2 is more compact and browner in colour, and is traversed in all directions by small joints.

It also contains specks of the fossil resin. Samples assayed in the Survey laboratory by Sub-Assistant Hira Lal gave the following satisfactory results:—

	Seam.	
	No. 1.	*No. 2.*
Moisture	5·84	3·02
Other volatile matter	35·16	39·58
Fixed carbon	50·40	50·80
Ash	8 60	6·60
	100 00	100·00

No. 1 does not cake; ash pale red.
No. 2 cakes; ash red.

Probable extent of the field.

The section examined is very similar in some respects to one described by Captain H. H. Godwin-Austen (Jour. As. Soc. Bengal, Vol. XXXVIII, Pt. II, No. 1, 1869) as occurring on a small tributary of the Umblay near the village of Nong-kerasi, about 10 miles to the north-west of Borsora; but to determine whether the coal-measures are continuous between these points would require a more detailed examination of the district than I was able to make. The only means of getting sections in such a country is to follow up the hill streams in which fragments of coal are found to the outcrop of the seam, and at this season (June) these streams are liable to sudden floods and become quite impassable. If it should be found that the coal does extend between these points, its amount must be very large.

Position of the seams as regards extraction of the coal.

The outcrop near Borsora is very favourably situated for being worked. It is not more than half a mile within the hills and at a low elevation above the plain. The coal rises from the outcrops so that mines or quarries could be easily drained. The foot of the hills is only 1 mile from the Patlai river, a branch of the Jadukhata, and during the rains boats can come up to within a few hundred yards of the hills.

Even now great numbers go close to the spot during the rains to carry away limestone from the numerous quarries between Borsora and Lakma.

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RECORDS

OF THE

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Part 4.] 1883. [November.

Palæontological Notes from the Daltonganj *and* Hutar coalfields *in Chota Nagpur,*
by OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

THE above two coalfields were surveyed by Messrs. Hughes[1] and V. Ball[2] respectively, but no fossils were known from either of them. It was, however, of interest to ascertain whether fossils occurred there and of what character they were, as it was quite to be expected that some portion of the coal beds in one or the other might be of the age of the Karharbári beds. I was consequently last winter deputed to visit these coal-fields and to examine them for fossils. The results were satisfactory enough, as not only were fossils met with in good numbers, but they were also sufficiently clear to allow of some of the horizons being fixed with much probability.

The Daltonganj coalfield.

This coalfield is situated about 50 miles west of Hazáribágh, and is traversed by the Koel and Amánat rivers. The rocks represented in the coal-field are the Talchirs and the coal-measures. These were hitherto assigned to the Barákar group of the Damuda subdivision of the Gondwána system. The examination of the fossils, however, showed that these coal beds of the Daltonganj field most probably are of the age of the Karharbári beds.

The various outcrops in this field are described in Mr. Hughes' report; I visited most of them with the view of examining them for fossils.

Outcrops at Singra.

At the junction of the Koel and Amánat rivers, about 5 miles north of Daltonganj, near Singra, where mining is carried on to some extent, there is a good exposure of the coal-bearing rocks, consisting of sandstones and sandy shales, with three outcrops of coal seams.

The base of the section close to the river surface consists of a series of sandy micaceous grey shales, which are on the whole unfossiliferous; but very

[1] Mem. G. S. I., Vol. VIII, Pl. 2.
[2] *Ibid*, Vol. XV, Pl. 1.

nearly at the base there is a stratum in which some leaf impressions occur; they are not very distinct, though the following can be recognised:—

Gangamopteris cyclopteroides var. *attenuata*.
Glossopteris communis, Feistm; large leaves.
„ *indica*, Schimp.

The stratum immediately above this bed contains root-like impressions traversing the rock in various directions; in some cases they appeared to me to be of *Vertebraria*. Above this bed is the coal outcrop, representing the first seam of the series.

Above this follows a series of sandstones and shales, without any trace of fossils, underlying the second seam. Above this seam there follows a series of grey sandy shales, with a band of hard and light grey shale.

The third seam, which now follows, is not exposed in this section on the river, but a little further to the south. In a soft fine shale, of grey colour with reddish tints, above this seam the following fossils were found:—

Vertebraria indica, Royle.
Nöggerathia hislopi, Bunb. (Feistm.); numerous.
Samaropsis parvula, Heer.
Seeds, may be of the foregoing species.

These fossils, though not very numerous or quite decisive, yet show an ensemble like those from the third Karharbári seam or from the Mohpáni coal seams, both of which, there is little doubt, belong to the Karharbári beds.

This Karharbári character of the fossils is, however, more distinctly expressed in some other outcrops to the north of Singra.

Outcrops at Rajhera.

There is no mining carried on at present at this place, though there are traces of old workings; there is, however, no want of outcrops, one of which yielded a good number of fossils.

In a nala to the south of Rajhera there are at first sandstones like those above the first seam at Singra. Lower down below the sandstones there is an outcrop of grey sandy micaceous shales, about 5 feet thick; in about the middle of these shales, and I think representing the coal outcrop, is a band of a darker shale, which breaks irregularly, with somewhat a sphæroidal structure. I think this outcrop represents the first seam of Singra.

The above-mentioned dark shale band is full of leaf impressions, which are in most cases very well preserved, and amongst which the following species could be recognised:—

Glossopteris communis, Feistm.; very large leaves with a thick midrib and very close and narrow meshes.
Glossopteris indica, Schimp.
„ *decipiens*, Feistm.; one specimen like the species from the Karharbári coalfield.
Gangamopteris cyclopteroides, Feistm. The true original form like in the Talchirs and Karharbáris; in various states of preservation, but also showing distinctly the basal portion.

Gangamopteris var. *subauriculata*; one nice specimen, with doubled up margin.
" var. *attenuata*.
Samaropsis, comp. *parvula*, Heer; just like some from the Karharbári beds.
Voltzia—a branchlet of a coniferous plant, belongs I think to this genus.

There are some other shale outcrops east of Rajhera, which, however, did not yield many distinct fossils, though the rock in which they occurred, a sandy shale of greenish-brownish colour with reddish tints, resembles one in the Mohpáni coalfield containing fossils of the Karharbári type. The only fossils in the present instance were: *Glossopteris communis*, Feistm., and *Equisetaceous* stems.

A comparison of the fossils named above with those from other coalfields will show that they bear the character of those known from the Karharbári beds, and there is little doubt that the coal seams of the Daltonganj coalfield, at least those where fossils were found (at Singra and Rajhera), are of the age of the Karharbári beds, which circumstance would perhaps add not a little to the importance of the coalfield.

The Hutar coalfield.

From this coalfield, which is situated on the Koel river to the south of the Daltonganj field, and which was surveyed by Mr. Ball, I have also brought a few fossils. I visited first the outcrops on the northern margin, south of the village Nowadih. Here the coal-bearing rocks are in contact with the Talchirs. Following a nala which joins the Supuhi river close to where the road from Daltonganj crosses the former, at first several outcrops are found between massive sandstones with a south-west dip; in these no fossils were found. Further on, close to the junction of the coal-bearing rocks with the Talchirs, there are other outcrops of strongly carbonaceous shales, quite close to the Talchirs, in which the following fossils were found:—

Gangamopteris cyclopteroides, Feistm.
" var. *attenuata*.

These carbonaceous shales pass without break into strata which belong to the Talchirs, and are conformable with the former; the rock is, however, not of the usual kind, being still somewhat carbonaceous shale, although undoubtedly already in the Talchirs; here also some fossils were found:—

Equisetaceous stems.
Gangamopteris cyclopteroides, Feistm.; typical form.
" var. *subauriculata*.

If we consider now these latter as belonging to the Talchirs, then the carbonaceous outcrops in close proximity to them are perhaps either of the same age, or else represent the Karharbári beds, while the higher outcrops would have to be considered as representing the Barákar group. This is the only locality where these relations could be recognised.

Further to east, at the village Hutar, there are again some outcrops, also apparently in conformity with the Talchirs; some fragments of fossils were found, but insufficient to determine the horizon; I should, however, feel inclined to consider them as Barákars.

Somewhat better fossils were met with near the east end of the field, north of Saidope. At the confluence of the Dauri and Ghorsam streams there is a great display of beds. At the bottom of the section close to the river surface is coal, over it lies coaly shale, then grey sandy shales, above which follow sandstones of yellowish and reddish colours.

The fossils occurred in the black coaly shale above the coal, and the following could be recognised :—

> *Equisetaceous* stems; very numerous.
> *Glossopteris indica*, Schimp.
> " *damudica*, Feistm.
> *Coniferous* branch like *Voltzia*.

To judge from these fossils, the outcrops can be considered as belonging with great probability to the Barákars, and the same appears to be the case with the other outcrops in the field, so that only on the northern margin of the field would the fossils allow of a more varied grouping of the beds.

Some of the fossils gathered on this occasion from the Daltonganj and Hutar coalfields will be figured in the Palæontologia Indica, together with some others collected on a previous journey in the Aurunga and Káranpura coal-fields.

On the altered basalts *of the* Dalhousie *region in the* North-Western Himalayas, *by* COLONEL C. A. MCMAHON, F.G.S.—(*With two plates*).

In my paper on the Geology of Dalhousie, I have already described the mode of occurrence of the rocks of the volcanic series in the Dalhousie area, and it only remains to note their petrological characteristics as seen in thin slices under the microscope.

Specimens from the Bagrár ridge.

No. 1.—A dull green amygdaloidal rock weathering to a light brown colour. Sp. G. 2·85. The amygdules are of small size and are composed of scolecite, delessite, and a red zeolite. A little iron pyrites is to be seen here and there.

M.—This slice closely resembles an undescribed specimen of the Darang traps. Augite is abundant, and is in irregular-shaped elongated pieces; none of it is fresh, and the felspar is also considerably kaolinised. Viridite is abundant, and the slice contains epidote in a granular form. Scolecite not only fills amygdules, but has replaced much of the original material in their vicinity.

No. 2.—A greyish-green amygdaloidal rock weathering to a light brown. Sp. G. 2·86. The amygdaloidal cavities are filled with quartz and scolecite, and specks of iron pyrites are to be seen here and there in the rock.

M.—The amygdules are composed of scolecite, quartz, and viridite, the latter containing many crystals of epidote. Cracks in the rock and in the amygdules are filled with viridite and a yellow substance resembling epidote. The viridite is of the serpentinous variety.

The augite is altered almost past recognition, but it can be doubtfully made out here and there with the aid of polarised light. The small felspar prisms are still to be traced, but all signs of twinning has disappeared, and the felspars have been so eaten into, and replaced by the green alteration-product, that their outline is irregular. The whole rock is permeated through and through with this green product of alteration, and all the outlines of the original minerals have become confused and hazy. No trace of magnetite remains.

The quartz which occurs in the centre of an amygdule surrounded by scolecite has a dusty appearance, which on the application of high powers (× 300 to 500) is seen to be caused by a multitude of extremely minute liquid cavities, many of which have movable bubbles. The liquid in some of the cavities is red coloured. The quartz appears to have formed after the scolecite which lines the amygdaloidal cavities, as it conforms itself to the outward form of the scolecite crystals.

No. 3.—A grey-green compact rock. Sp. G. 2·81.

M.—This is quite a typical lava. The base which forms a prominent object in the field of the microscope is considerable in amount in proportion to the imbedded crystals, and probably constitutes more than one-half of the whole. It is greenish-white in reflected, and something between a brown and an olive green in transmitted, light. It is not at all dichroic, and it does not polarise between crossed nicols, but changes from dark to its natural colour, much light, however, being absorbed. Under high powers it is resolved into very minute granular matter. This base is evidently a partially devitrified glass and represents the residuum left uncrystallized owing to the rapid cooling of the rock.

In this base, besides the larger crystals to be described further on, minute crystals of felspar, often acicular in shape, are scattered about, which are I think very characteristic of a rapidly cooled lava. Some of them have enclosed portions of the base, as in fig. 7, plate II, whilst others are in skeleton or incomplete forms similar to those depicted at figs. 1, 3, 4, 5, and 6, which are given as samples only, the shape of these minute crystals being very varied.[1]

In this base, besides the minute crystals just described, comparatively large ones of felspar and augite are arranged in clusters and groups.

In my paper on the basalts of Bombay I described the penetration of felspar by augite and of augite by felspar as a structural peculiarity very characteristic of volcanic rocks. This structure is more than usually prominent in this slice; indeed a large proportion of the augite and felspar crystals are interlaced and intermixed in a way that is very striking, and is often very complex. It would seem as if the first formed crystals floating about in the fluid base before they attained any size were drawn together by mutual molecular attraction, and that

[1] Figs. 5, 7, and 10 closely resemble some of the figures depicted in fig. 4, plate XI, Zirkel's Microscopic Petrology of the 40th parallel. Zirkel considers the forms shown in fig. 8, plate XI of his work above quoted as "probably a felspathic crystalline product of devitrification." Unfortunately "devitrification," as at present used by microscopists, is a very ambiguous term; thus Mr. F. Rutley, in a paper published in the Q. J. G. S. XXXVI, 407, writes of a rock described therein: "In the first case, it may be regarded as an obsidian devitrified *at its birth*; in the second, as an obsidian devitrified *in its old age*." Does Zirkel mean that the skeleton crystals he describes are congenital or epigenital? If the latter, I think he has missed the point of the matter. I think these imperfect forms are the result of rapid cooling and correspond to the skeleton crystals of slags.

the growth of the crystals then went on side by side so rapidly that they embraced and interlaced each other in the act of crystallization.

At fig. 1, plate I, the sketch of a portion of this slice, magnified 30 diameters, is intended to give a general impression of its appearance in the field of the microscope, and the way the imbedded crystals of augite and felspar group themselves together in the base—one long band of the associated minerals forming a sort of festoon across the centre of the field.

At fig. 2 of this plate I have given a sketch of another portion of the same slice, magnified 60 diameters. The singular way the augite has embraced the felspar prisms is shown in the sketch. The feathery kind of termination of some of the felspars reminds me of those shown at fig. 2, plate I, of the illustrations to my paper on the Bombay basalts, and suggests the feathery terminations, described by Dr. Sorby, of the felspar of slags.

Other illustrations of the intergrowth of augite and felspar are given at figs. 2, 8, 9, and 11, plate II.

In a previous paper I quoted a passage from Dr. Geikie on the Volcanic rocks of the basin of the Firth of Forth, showing how felspar prisms "shoot" through crystals of augite as though they were "intrusive." Such figures, as the extraordinary ones represented at figs. 9 and 11, plate II, certainly imitate "intrusion" in a remarkable way, and at first sight suggest the idea that the felspar must have filled cracks in the augite crystals at a period subsequent to the genesis of the augite; but, I think these singular appearances are simply due to the fact that the crystallization of both the felspar and augite proceeded rapidly at the same time, and that the supply of material for the formation of the two minerals fluctuated. It will be observed, moreover, in fig. 2, plate I, and in figs. 2 and 9 of plate II, that the felspar is attenuated in the centre of the augite and expands rapidly at the edges. I have observed this to be a general rule, and have seen many cases of it much more striking than those in the illustrations to which attention is directed; and I think this peculiarity shows that the augite did not crystallize around previously formed felspar prisms, but that the crystallization of the two minerals proceeded simultaneously, and that the supply of felspathic material was, for a time, cut off by the vigour with which the molecules of augitic matter came together.

In fig. 2, plate I, and figs. 1, 2, 3, and 9 of plate II, I have attempted to illustrate a tendency observable in felspar crystals to fray out at their ends, or rather to throw off long hair-like prisms or appendages. This peculiarity is another indication, I think, of rapid cooling, showing that as crystallization proceeded, the supply of material was cut off by the loss of perfect freedom of molecular motion consequent on cooling; hence these crystals were unable to assume a perfect crystallographic form.

I dwell upon these details at some length, because they are not without interest in themselves, and because it is chiefly by noticing characteristic structural peculiarities that we are able to distinguish between basic volcanic and basic plutonic rocks.

All the augite in this slice is of irregular shape; a few crystals only are twinned.

If we except the minute crystals just described, and those caught up in augite, the felspar crystals seen in this slice are as a rule well shaped, though many, even of these, are frayed out at one end; that is to say, they have thrown out one or more long and slender terminal prisms indicating that their crystallization, though deliberate at first, was ultimately brought to a sudden and rapid termination.

Here and there the felspar exhibits the multiple twinning of triclinic felspar; a few sanidine prisms exhibit single twinning; but in most of the crystals all trace of twinning is absent. The substance of the prisms has been much invaded by greenish granular matter similar to that seen in the base, and it is difficult to say whether it was caught up in the act of crystallization or whether it is the result of subsequent alteration.

The slice contains no magnetite, and some of the felspar is sanidine. There are a few fields of viridite in the slice.

No. 4.—A greenish-grey compact rock weathering to a light brown colour. Sp. G. 2·84.

M.—This slice exhibits the usual arrangement of felspar and augite scattered about in a devitrified glassy base. Some of the felspar is seen to be triclinic, but in the majority of cases, owing to kaolinisation, the twinning is no longer to be traced. I think, however, from a consideration of the azimuth at which extinction occurs, that some of the felspars are probably sanidine.

This slice contains numerous instances of the enclosure of the glassy base by felspar in the act of crystallization, similar to those already described. An illustration of one of these is given at fig. 10. In some instances these enclosures run the whole length of the prism and maintain a uniform thickness throughout. Another illustration of one of these enclosures is given at fig. 12, plate II.[1] In this case the magma enclosed has thinned away towards the centre of the prism, being thick at both ends. It is not a case of two prisms in close conjunction as one might suppose from the illustration, but of one prism with the glassy base caught up in it.

The augite in this rock is much altered. The slice contains several cracks, filled with quartz, which die out within the slice itself—cracks formed I presume on cooling.

No. 5.—A greenish-grey compact rock, brown and rotten at the edges. Sp. G. 2·69.

This rock occurs on the margin of the outcrop where the trap first appears.

M.—The whole ground mass has been converted into viridite in which the felspar crystals are starred about.

Here and there the triclinic character of the latter can be made out, but their internal structure has been a good deal altered into granular matter. Scattered through the slice are granules of a dichroic yellowish mineral which appears to be epidote. Its shape is irregular and its internal structure is micro-granular. No augite is visible.

[1] This crystal somewhat resembles one of the crystallites in pearlite depicted at fig. 20, plate I, Zirkel's Microscopic Petrology of the 40th parallel.

Descent from Dhalog to Sandára on the Ravi.

No. 6.—A greenish-grey compact rock weathering brown. Sp. G. 2·80. This rock occurs where the trap first crops out.

M.—One of the first objects that strikes one on looking at this slice is the abundance of the light brown glassy base which is partially devitrified into fine-grained granular matter. In this base crystals of felspar and augite are scattered about. Very little magnetite or ilmenite is to be seen, but there is much leucoxene, the product of the decomposition of the latter.

Much of the felspar is seen to be triclinic, but some of it is sanidine, and probably both are equally abundant. The felspar is considerably decomposed by the invasion of viridite, and part of it is coloured red by the presence of fine granular matter in it which is too minute to be determined.

Augite is abundant in irregular shaped prisms, and much of it is twinned. It is not in a fresh condition, but its alteration is not in an advanced stage.

Water has percolated freely through the rock, and meandering lake-like spaces, plugged with scolecite and viridite, are to be seen here and there. Flakes of mica are scattered through the viridite.

The penetration of augite by felspar prisms, which are more attenuated in the middle of the augite than towards the margin of the latter, similar to those previously described, is very frequent.

No. 7.—A greenish-grey compact rock, somewhat mottled in appearance. Sp. G. 2·84.

M.—This slice in its general aspect very closely resembles No. 3, except that the felspar prisms and augite crystals are better formed and are of more regular shape.

The felspar is almost completely kaolinised, and all trace of twinning has consequently been obliterated. Nearly all the augite is partially altered. No unchanged magnetite is discernible in this slice or in No. 3. A portion of this slice is depicted at fig. 3, plate I.

No. 8.—A greenish-grey compact rock with streaks of epidote in it. Sp. G. 2·87.

M.—Epidote, associated with quartz, forms large veins running through the rock and takes up the greater part of the slice; whilst smaller veins of epidote alone, and of quartz alone, traverse it in other directions. The general mass is likewise much penetrated by epidote. The epidote is in a minutely granular condition, though well shaped microscopic crystals are to be seen in abundance along the edges of veins.

The rock itself consists of the usual felspar crystals starred about in a devitrified glassy base. All the felspar crystals are greatly altered and invaded by granular matter. No unaltered augite remains, and nothing distinctly recognisable as augite. Rod-like and dendritic forms of magnetite are abundant in the base.

No. 9.—A greenish-grey compact rock. Sp. G. 2·76.

M.—Augite is abundant and is in rather massive, irregular shaped prisms. The slice contains, however, one long slim augite. Twinning is not common. All the augite is more or less browned as the result of partial alteration.

The felspar is in well-shaped prisms of moderately large size. It is much kaolinised, and the twinning can only be made out here and there. The slice apparently contains both plagioclase and sanidine.

Amygdules of viridite (delessite ?) and scolecite are prominent, and flakes of mica are to be seen in both. All the ilmenite has been converted into leucoxene.

Trap from the Ravi section between Simliu and Kairi.

No. 10.—A mottled greenish-grey compact rock. Sp. G. 2·78.

M.—Augite is abundant in this slice, but it is all more or less altered and converted here and there into a serpentinous product.

The felspar is greatly kaolinised. A serpentinous variety of viridite is abundant and contains some crystals of epidote.

Here and there the original glassy base, now partially devitrified, is still to be made out.

No. 11.—A mottled greenish-grey compact rock. Sp. G. 2·86.

M.—This slice is very similar to the last, but the augite is still more altered.

An irregular vein filled with epidote meanders through the slice. The triclinic character of some of the felspar can still be discerned, but the rest is completely kaolinised.

No. 12.—A pale greenish-grey, perfectly compact rock with a vitreous aspect. Sp. G. 2·84.

M.—The slice consists of a devitrified glassy base in which numerous crystallites of felspar are starred about. The base is composed of micro-granular matter of grey colour with a faint greenish tinge in it. Diffused through this are patches of minutely granular matter, of irregular outline, that polarises between crossed nicols. It is probably imperfectly formed epidote and may possibly represent pre-existing augite.

The slice is traversed by numerous veins filled with crypto-crystalline and apparently felspathic material crowded with countless, colourless, hair-like microliths. These veins were apparently filled by an exfiltration process during the cooling of the rock.

Below the Staging Bungalow Mámul to the west.

No. 13.—A mottled compact rock varying from green to purple. Sp. G. 2·73. B.B: fuses to a black magnetic bead.

M.—This slice consists of a glass, partially devitrified and exhibiting flow structure, containing a large amount of ferruginous, minutely granular material, arranged in flocculent masses. Much of it is peroxidised, and this imparts a red appearance to the slice in reflected light. In this base are scattered minute and irregular shaped prisms of felspar which exhibit no twinning. A comparatively large one has the multiple twinning of a triclinic felspar. Here and there patches of leucoxene are to be seen, but no augite.

The slice contains a few shapeless grains of a dichroic and minutely granular mineral ich appears to be epidote.

No. 14.—A greenish-grey compact rock. Sp. G. 2·86. B.B: fuses easily to a dark bead.

M.—This slice consists of a devitrified glassy base in which imperfectly formed crystals of felspar are scattered about. It very much resembles No. 12.

Conclusion.

All the above specimens give abundant evidence of having been lavas erupted at the surface of the earth's crust. No existing volcano could yield a more typical lava than No. 4.

The Dalhousie traps appear, on the whole, to belong to the basic type. No. 5 may possibly belong to the intermediate series, but No. 13 was evidently a highly glassy rock, approximating to a basalt glass, and No. 5 may have belonged to this class also.

Augite is abundant in all the other specimens except in Nos. 12 and 14 (in which it is wanting); and their specific gravity ranges from 2·76 to 2·87; their average being 2·83. The specific gravity of Nos. 12 and 14 is 2·84 and 2·86. All the specimens described in this paper, except No. 5, clearly belong to the basic class.

Sanidine is present in most of the specimens, but it plays a subordinate part. The presence of a small amount of sanidine, even in true basalts, is not specially remarkable.[1]

Considering the extent to which alteration has proceeded, the absence of olivine was only to be expected, for it is one of the first of the basaltic minerals to decay, and it may have furnished the materials for the formation of some of the secondary minerals so abundant in these rocks. On the whole, I think, the Dalhousie traps may be classed as altered basalts.

The next question which arises is whether the microscopical examination of these rocks throws any light upon their geological age.

The idea that basalts are tertiary rocks has long since been exploded, and it is now known that they may be of any age. Moreover, those who formerly held that basalts are of tertiary age would probably have classed the rocks now described as melaphyres. I discard the name melaphyre myself, because its use is apt to be misleading, inasmuch as altered plutonic rocks are sometimes included under that term.

All the specimens examined show that the Dalhousie traps are greatly altered. In none is the augite fresh; whilst in some it is altered almost past recognition.

The felspar is, as a rule, more or less kaolinised; whilst throughout the slices secondary products are abundant.

The extent to which alteration has proceeded in these rocks is in my opinion a good argument in favour of their being of considerable geological age.

The alteration exhibited appears, from the aspect of the rocks under the microscope, to have been the result of either the slow percolation of water or of hydro-thermal agencies. This alteration is not a mere local peculiarity, but appears to prevail throughout these rocks and to extend over a large area.

Considerable time must surely have been required for the production of the uniform changes to be seen in these dense traps. In the absence of evidence to

[1] See Zirkel's Microsco c Petrology of the 40th Parallel, pp. 216-229.

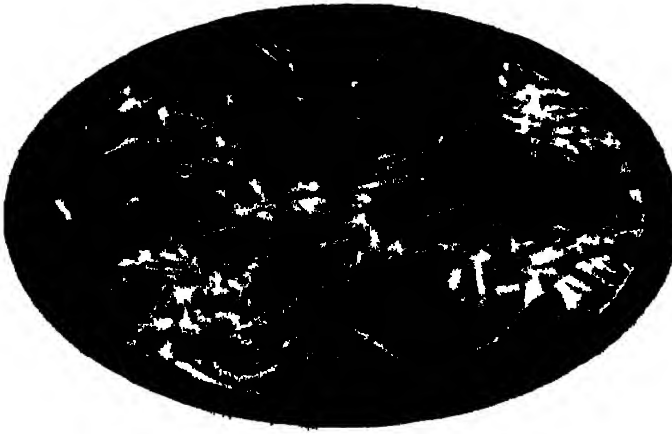
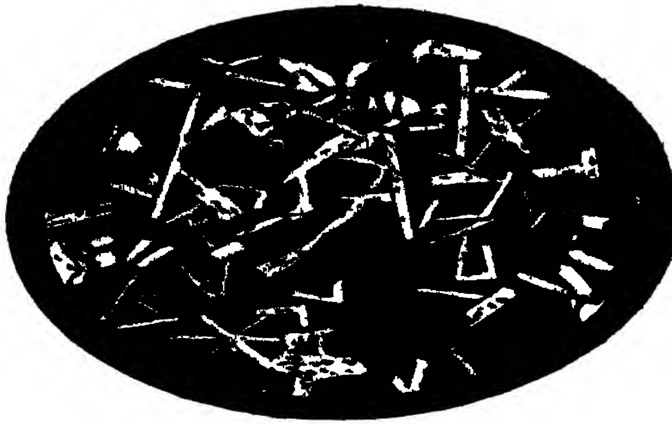


Fig. 1 × 80

Fig. 2 × [illegible]



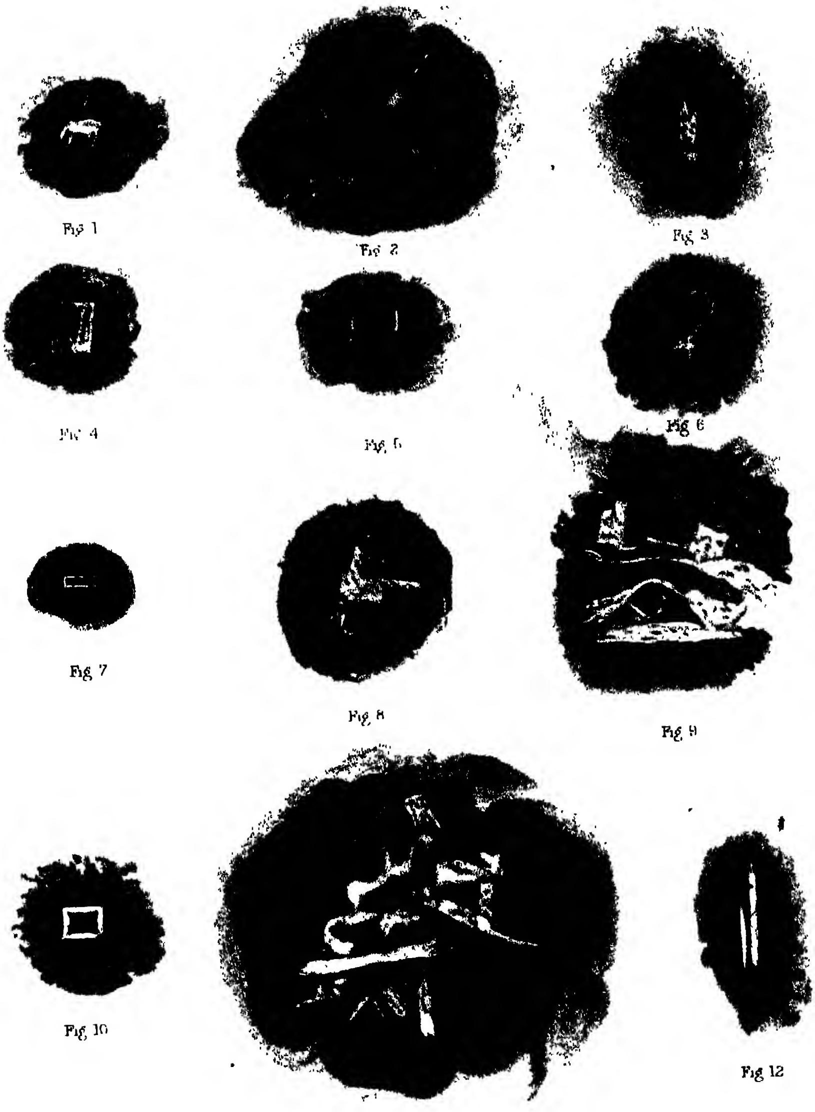


Fig 1 Fig 2 Fig 3

Fig 4 Fig 5 Fig 6

Fig 7 Fig 8 Fig 9

Fig 10 Fig 11 Fig 12

Reproduced in heliogravure from the original drawings at the Surveyor General's Office, Calcutta.
November 1883

the contrary, I think we may safely conclude that the extent of alteration affords, in a rough way, a measure of the age of these rocks.

The basalts of Bombay are believed to be of upper cretaceous or lower tertiary age; and if we compare the extent to which alteration has proceeded in the two rocks,—both being basic lavas of much the same character—I think it is logical to infer, unless and until evidence to prove the contrary can be adduced, that the traps of the Dalhousie area are considerably older than the basalts of Bombay. The result of their examination under the microscope is therefore to support the conclusion, as to the age of the traps described in this paper, arrived at on other grounds in my paper on the geology of Dalhousie.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Altered basalt. Dalhousie. Slice No. 3. Sketch intended to give a general idea of the way the augite and felspar crystals are interlaced and grouped together in clusters.

Fig. 2. Another portion of the same slice showing the feathery terminations of some of the felspar crystals and the intergrowth of augite and felspar consequent on the simultaneous crystallization of these minerals.

Fig. 3. Altered basalt. Dalhousie. Slice No. 7. Crystals of felspar and augite are seen scattered about in a partially devitrified glassy base.

PLATE II.

Fig. 1. An incomplete or skeleton form of felspar crystal. Slice No. 3. The result of rapid solidification.

Fig. 2. Intergrowth of augite and felspar, the result of rapid cooling. Slice No. 3.

Fig. 3. Another skeleton form of felspar crystal. Slice No. 3.

Fig. 4. Ditto.

Fig. 5. Ditto.

Fig. 6. Ditto.

Fig. 7. Skeleton crystal of felspar which has, owing to rapid cooling, enclosed a portion of the base. Slice No. 3.

Fig. 8. Intergrowth of augite and felspar. Slice No. 3.

Fig. 9. Ditto.

Fig. 10. Enclosure of the base by a skeleton crystal of felspar. Slice No. 4.

Fig. 11. Intergrowth of augite and felspar. Slice No. 3.

Fig. 12. Enclosure of glassy base by skeleton crystal of felspar. Slice No. 4.

On the microscopic structure *of some* sub-Himalayan rocks *of tertiary age, by* COLONEL C. A. MCMAHON, F.G.S.

No. 1.—A fine-grained sandstone of the Sirmur series, containing a fossil leaf, found by Mr. Medlicott south-east of Chune, on the Ravi. The following note on this specimen is taken from the Records of the Survey of India, Vol. IX, p. 52:—"In this very crushed, probably inverted, outcrop I found a characteristic sample of the Kasauli plant bed, the only occurrence of it known west of the Sutlej."

M.—The grains of quartz in this slice are nearly all angular, and only a few here and there are subangular.

Grains of granular limestone are numerous, and one fragment of felspar is present. Leaves of biotite (?) and muscovite are to be seen here and there, and are evidently original constituents of the rock and were deposited along with the sand. The leaves of mica are bent round and conform to the external shape of the grains between which they are jammed. The sand of our Panjab rivers is full of fragments of mica.

The slice contains some green dichroic grains that may have resulted from the degradation of trap. It also contains fragments of garnet and of schorl.

The interstitial mud has been converted into a crypto-crystalline material.

I have only detected liquid cavities, with movable bubbles, in one grain of quartz. The bubbles are extremely small ones.

Specimens of fine-grained sandstones from Bhond.[1]

No. 2.—This specimen closely resembles the last described. It contains fragments of schorl, muscovite, and green mica. Grains of calcite are present, but they are not so abundant as in the last. There are some micro-garnets and a little hæmatite. I have observed no liquid cavities in the quartz.

No. 3.—The same as the last. The slice contains four minute fragments of plagioclase. Calcite is sparce, and the quartz contains no liquid cavities with bubbles.

No. 4.—This specimen is very similar to the preceding ones. It contains more calcite than the last and more argillaceous material. It contains neither schorl nor garnet, but liquid cavities with movable bubbles are present in the quartz.

No. 5.—The grains of quartz are in angular fragments closely dovetailed together. The interstitial mud which occurs in patches is dark between crossed nicols showing doubly refracting fibres scattered about in it, apparently of felspathic material.

The slice contains some grains of schorl and fragments of green mica and muscovite. Some of the grains of quartz contain liquid cavities with movable bubbles.

In this, and one of the previous slices, a quartz grain contains a microlith with an internal shrinkage cavity,—a circumstance that indicates an igneous

[1] Records XVI, p. 35.

origin and shows that the grain of quartz was derived from the waste of granite or similar rock.

No. 6.—This slice consists of fragments of quartz and a muddy cement converted into a crypto-crystalline material; it contains fragments of schorl, muscovite, green mica, calcite, and one of garnet. There are patches of chloritic material here and there.

Some of the quartz grains contain liquid cavities with movable bubbles.

Red clays—Bhond.

No. 7.—This consists of angular pieces of quartz and fine fragments of muscovite imbedded in very fine red mud. Patches of hæmatite are present here and there.

No. 8.—Much the same as the last specimen. There is less mud and more fine-grained siliceous material and more white and green mica. The slice is of somewhat variegated colour owing to the presence of dark and clear irregularly defined bands.

In one of the quartz grains I detected liquid cavities with small movable bubbles.

No. 9.—Much the same as No. 7. Muscovite is more sparse, and I have not detected any liquid cavities in it.

Kasauli sandstones.

No. 10.—This slice consists of angular fragments of quartz and patches of consolidated mud; it contains pieces of schorl, leaves of silvery and of a yellowish-green mica; also a piece of triclinic felspar; a few small garnets and a fragment of a larger one.

Some of the quartz grains contain movable bubbles, but they are small and sparce. One grain of quartz contains a microlith of hornblende, in which are numerous grains of opacite and several enclosures with fixed bubbles in them. Another quartz grain is full of transparent hair-like belonites. This specimen contains no calcite.

No. 11.—This slice greatly resembles the last. It contains muscovite, a reddish-brown mica, schorl, numerous large pieces of garnet, a little granular calcite, a fragment of epidote and fragments of a carbonaceous slaty rock. The muscovite is in good-sized leaves.

Some of the grains of quartz exhibit a polysynthetic structure, whilst others contain microliths of muscovite similar to those so characteristic of the gneissose granite of the North-West Himalayas. There are some fragments of crypto-crystalline mica (another characteristic of the gneissose granite) and a grain of fibrous felspar (a form of microcline,—see Records XVI, 131).

There is a small fragment of triclinic felspar and, I think, of decomposed orthoclase.

Some of the quartz contains liquid cavities with movable bubbles.

Bakloh sandstones.

Nos. 12 and 13.—These slices consist of angular and sub-angular grains of quartz set in mud. The quartz is not very clear or pellucid, being here and there.

milky and opaque; and some of the grains exhibit a polysynthetic structure. The earthy portion is stained yellow with oxide of iron, and here and there brown dots appear which are probably limonite.

No calcite or mica is present, but there are a few small fragments of a dichroic mineral that may be schorl.

No. 12 contains cavities with bubbles, but not movable ones.

No. 14.—This rock so closely resembles the Kasauli sandstone that a separate description is unnecessary. Schorl, a small garnet, and a little felspar are present in the slice. The quartz contains liquid cavities with movable bubbles and stone cavities with fixed bubbles and mineral deposits. Muscovite is sparce.

Dagshái sandstones.

The specimens described below were taken from the side of the Simla cart road facing Dagshái.

Nos. 15, 16, and 17.—These are seen under the microscope to be composed of fragments of quartz and of slaty rocks, some of which appear to be carbonaceous. Fragments of well crystallised calcite and of schorl are also present. Each slice contains a few pieces of triclinic felspar, one of which includes microliths of muscovite. Leaves of muscovite and a yellowish-green mica are abundant.

One of the grains of quartz has crypto-crystalline mica attached to and penetrating it. It has all the appearance of being a fragment of the gneissose granite. There are also separate fragments of the crypto-crystalline mica. Some of the quartz grains are polysynthetic.

A few small garnets are present, and liquid cavities with movable bubbles are abundant in the quartz.

Siwalik series (Nahan beds ?), Naini Tál road.

Nos. 18, 19, and 20.—These consist of angular pieces of quartz, bits of slate, and a little mud, the quartz predominating. Leaves of muscovite and a greenish mica and fragments of schorl are present in the slice. Some of the quartz grains contain microliths of muscovite similar to those contained in the gneissose granite. Some of the quartz is milky and opaque, and none of it is particularly hyaline.

Liquid cavities are numerous in the quartz, but those with bubbles are comparatively sparce.

Nahan sandstone—Nalagarh.

No. 21.—This slice consists of angular and sub-angular grains of quartz, quartzite, slate, limestone, schistose rocks, and kaolinised felspar, cemented together with mud. Some of the slate appears to be carbonaceous.

A good many of the grains of quartz are of polysynthetic structure similar to the fish-roe grains of the gneissose granite. The slice contains a fragment of triclinic felspar and a few of the foliated variety of microcline. Much of the quartz is milky and opaque; muscovite is present and also a few fragments of schorl.

Liquid cavities with movable bubbles are numerous in the quartz; also air cavities.

Nahan sandstone—Mailog.

Nos. 22 and 23.—These specimens are composed of angular grains of quartz imbedded in fine mud of greenish colour. The slices contain fragments of schorl and the quartz liquid cavities with movable bubbles.

Siwalik (?) sandstone. Dhár.

The undoubtedly Siwalik sandstone of the outermost range is too friable to admit of slicing, but except in induration it seems lithologically identical with the Dhar rock.

No. 24.—This slice very much resembles No. 21 in its general appearance under the microscope and in the nature of its contents. Both contain fragments of red quartzite, green schists containing magnetite that remind me much of hornblendic beds near Shiel, in the Jubal State, beyond Simla; and fragments of a rock that looks like a decomposed amygdaloid. No. 24 differs from No. 21 in containing fragments of a pink garnet, flesh-coloured in transmitted light. Muscovite is present in large leaves in No. 21, but in No. 24 no mica is present, except in the form of microliths in the quartz. No. 24, moreover, does not contain any "fish-roe" quartz.

Both rocks under the microscope are generally so similar, that if they do not represent the same beds, at any rate, some of the rocks that were exposed and in process of erosion when the Nalagarh beds were laid down must have been in process of erosion when the Dhar beds were deposited.

The slice under description (24) contains a doubly refracting mineral that appears to be schorl.

The garnets are full of air cavities; whilst liquid cavities with large movable bubbles are abundant in the quartz.

Conclusion.

A microscopic examination of the fine-grained earthy sandstone containing a a fossil leaf found by Mr. Medlicott in the Sirmur horizon on the Ravi, and of the beds trans-Ravi at Bhond, and of some of the beds under Bakloh (in which fossil leaves have also been found); and a comparison of these rocks with a thin slice of a typical Kasauli bed leave no doubt in my mind that the Kasauli leaf beds continue into the Dalhousie area.[1] Their position, in the Dalhousie region, appears to be near, but not on, the northern boundary of the outcrop of the Sirmur series.

The Kasauli leaf beds, in which name I include all those alluded to in the last paragraph, are composed of very fine-grained angular fragments of quartz, grains of calcite or granular limestone, fragments of carbonaceous slaty rocks, and consolidated mud. Leaves of muscovite and of a greenish mica—evidently original constituents of deposition—are squeezed between the grains of quartz;

[1] I have some very perfect fossil leaves imbedded in an exactly similar rock found by Mr. C. J. Rodgers at Dharmsala and given me by that gentleman.

whilst either minutely triturated fragments of mica are mixed up with the mud, or a portion of the latter has been converted into that mineral. The former explanation seems the more probable one.

Taking the specimens of the Sirmur series described in the preceding pages as a whole, they appear to have had their origin in the subaerial waste of the carbo-triassic limestones, infra-carboniferous slates, granitic rocks, and probably to a small extent of traps. The evidence afforded by the Sirmur sandstones on the latter point, however, is feeble.

A prominent feature in most of the slices is well crystallized or granular limestone, in fragments that have all the appearance of having been deposited with the other constituents of the rock. They are all isolated fragments; there are no veins or connecting links between them, and nothing to support the supposition that they have been formed by an epigenital process after the consolidation of the sandstone. I can only regard these as fragments of limestones, and I think the inference a natural one that the carbo-triassic series was exposed at the surface and was suffering denudation when these tertiary sandstones were formed. We know on other evidence that in the Simla area these limestones were deeply eroded by subaerial agencies[1] in pre-tertiary times.

The presence in these sandstones of fragments of carbonaceous slaty rocks that would answer well for the infra-Krol series also supports this view.

But infra-Krol and Krol rocks were evidently not the only ones that were suffering denudation in the Himalayan area when the Sirmur series were laid down. The presence of schorl, of a type characteristic of granitic rocks; of fragments of garnet, a mineral very abundant in such rocks in the North-West Himalayas; of muscovite and a dark green mica; of triclinic felspar, and of the fibrous variety of microcline, taken in connection with the character of the quartz grains, indicates, I think, clearly enough, that granitic rocks were also exposed at the surface and were suffering denudation when the sandstones were formed.

The schorl and muscovite I should say undoubtedly came from granitic rocks; the former is of the type characteristic of such rocks, and does not resemble the tourmaline found in the silurian sandstones of the Dalhousie area.

Garnets might of course be derived from a variety of rocks, but at the same time it must not be forgotten that this mineral is abundantly present in the granites and gneissose granites of the Himalayas.

But the character of the quartz is the most important point in connection with the subject under consideration. Liquid cavities with movable bubbles are abundant in many grains; in quite as large a proportion of grains as one could reasonably expect on the supposition that they were derived from Himalayan granitic rocks. Then we have grains containing microliths with shrinkage cavities in them, exactly similar to those found in our Himalayan granites; and in No. 10 we have a hornblende microlith containing several enclosures with fixed bubbles in them; whilst in No. 14 we find quartz grains containing stone cavities with fixed bubbles, and mineral matter either deposited by the mineral material of the "stone enclosure" on cooling, or caught up by it in the act of consolidation. All the above are eminently characteristic of granitic

[1] Manual, pp. 533, 569.

rocks and could be matched, over and over again, in the granites and gneissose granites of the Himalayas.

Other points to be noted are that some of the quartz grains exhibit a poly-synthetic structure, and that both quartz and felspar contain microliths of muscovite; whilst Nos. 15—17 contain fragments of crypto-crystalline mica, and a quartz grain penetrated by crypto-crystalline mica. The study of the granites and gneissose granites of Dalhousie and the Sutlej valley, under the microscope, has shown that polysynthetic quartz, microliths of muscovite in quartz and felspar, and crypto-crystalline mica are very characteristic of these rocks.

On the whole, then, I cannot doubt that much of the material of the Sirmur sandstones were derived from the waste of granitic rocks.

The comparative paucity of felspar may I think be explained by the fact that this mineral is not so hard as quartz, schorl, or garnet, and consequently must have suffered more than these minerals from trituration. It is moreover very liable to decomposition, and doubtless it was the felspar that suffered most in the passage of granitic detritus down the Himalayan streams and rivers, and supplied a considerable proportion of the constituents of the mud that forms the binding material of the sandstones. The felspar suffered more than the lime-stones, because, I presume, it had to travel further, and came from the axial ridges of the Himalayas, whilst the limestones were nearer home.

Mica is soft, but is very indestructible; and its very lightness and buoyancy in water doubtless preserved it from injury by the way.

Another question remains, namely, were the granitic materials derived directly from granitic rocks, or were they first deposited in ancient clastic rocks and supplied to the Sirmur sandstones on the breaking up of those rocks?

I do not think the latter supposition a probable one. The schorl and garnets are very fresh, and had they lain for long geological periods in ancient clastic rocks before they found a resting place in the Sirmur sandstones, I think they would have shown considérable signs of alteration or have been transmuted into other minerals that result from their degradation.

Assuming then that the granitic materials were directly derived from granitic rocks, the important question arises, were they derived from rocks now visible or from some others?

It does not seem probable that any granitic rocks can have been exposed in the Sirmur sandstone age other than those now visible. It is conceivable that some old intrusive sheets may have been removed by erosion, but they must have left their roots behind in any case.

That rocks of very similar appearance to the gneissose granites described in a previous paper, and which I regarded as of tertiary age, must have been exposed in silurian times, is clear, for the upper-silurian conglomerate contains boulders of granitoid gneiss. Samples of these boulders have not as yet been subjected to a critical examination in the laboratory, and it would be premature to express any decided opinion regarding the character of this granitoid rock; but whatever it may turn out to be, there seems to be no reason why we should suppose that granitic intrusions into the Himalayan area took place during one period only, or that they were limited to the special Himalayan disturbances of post-eocene times.

If these eruptions began in pre-tertiary or early tertiary times, the fact that gneissose granite had come to the surface and was suffering erosion when the Sirmur series were deposited presents no difficulty.

That the gneissose granite was already exposed when the Siwalik conglomerates were laid down, does not admit of a reasonable doubt, for the conglomerates are full of boulders of a rock undistinguishable from it; and the Siwalik conglomerates afford internal evidence of being derived from local sources.

In my paper on the microscopic structure of the Dalhousie gneissose granite (*supra*, p. 143) I spoke of this rock as of probably tertiary age and said that it was probably "brought into its present position in the course of the throes that gave birth to the Himalayas." Whilst I adhere to that statement, I desire to point out that it is not necessary for us to assign a late period in the tertiary age for the invasion of silurian beds by a hypogene rock of this character; or indeed to pin ourselves down to the tertiary period at all. The facts disclosed in this paper would harmonise better with the supposition that the eruption of the gneissose granite took place at a somewhat earlier date than that usually assigned to the beginning of the last series of special Himalayan disturbances.

It has been shown in the Manual of the Geology of India (pp. 525, 569-570) that the disturbing action proceeded with great slowness; that the Himalayan river gorges in Siwalik times were the same as now; that the sea was probably excluded from the sub-Himalayan region from early tertiary times; that elevation preceded compression; and "before any special contorting action had set in, the general condition of sub-Himalayan deposition had been established by a general (continental) elevation of the Himalayan area."

The Krol (carbo-triassic) rocks in the Simla area were deeply denuded by subaerial agencies (Manual, pp. 533-569) before the eocene nummulitics were laid down, and the Sabathu beds are "very variable in thickness suggesting a limit of deposition to the north-east." In other words, the Krol area in the Simla region was above water and formed dry land in pre-tertiary times; and if so, it seems only reasonable to suppose that the central axis of the Himalayas, if not throughout its whole length, had also, in part, at any rate, risen from the sea and formed more or less elevated land in pre-tertiary times, and so we find it stated in the Manual, page 571, that "a considerable Himalayan elevation occurred in pre-tertiary and early tertiary times."

The process of elevation doubtless was a slow and gradual one and extended over a lengthened period; but the "continental elevation" of the Himalayan area during a pre-tertiary period is just as likely to have been accompanied with hypogene granitic invasion of deep-seated rocks below the surface, as the subsequent period of special disturbances which took place during the tertiary period.

Whilst therefore I hold that the invasion of silurian rocks by gneissose granite was connected with the elevation and formation of the Himalayas, and think it probable that, in the Dalhousie area, the eruption of the gneissose-granite took place at the close of the eocene, or early in the miocene period; at the same time, I do not see that we need necessarily associate the eruption of all the gneissose granite of the North-West Himalayas, or indeed any of it, with the latest phase of the special disturbances which began in post-eocene times.

Note on the Geology of Jaunsar and the Lower Himalayas, *by* R. D. OLDHAM, *Geological Survey of India.* (With a map.)

1. The last season's work in the Himalayas having shown that the series as adopted ever since the publication of Mr. Medlicott's Memoir on the Lower Himalayas [1] requires some modification and extension to make it applicable to portions of the Lower Himalayas lying outside of the Simla section, it has been thought advisable to publish a short note showing the results of the resumed survey as far as it has gone; but while confining myself as far as possible to what may be said to be definitely proved, it will be impossible to steer clear of other points still doubtful, and these, which I shall distinguish to the best of my ability, must be taken with every necessary reservation.

2. One of the chief difficulties when starting work in Jaunsar, a district chosen chiefly on account of the fact that large scale maps were obtainable, lay in the fact that, with the exception of a great limestone series reasonably identified with the Krol, no representative of any of the sub-divisions established on the Simla section was to be recognised.

3. The oldest formation here, which I shall provisionally call the Chakrata series, consists of grey slates and quartzites, underlaid by a band of limestone generally some 300 or 400 feet thick, which is again underlaid by a great series of slates and quartzites marked by the prevalence of red and mottled beds. The principal exposures of the limestone lie in a zone running about east and west, and passing immediately to the south of the station of Chakrata; to the north of this zone the hills are formed of the underlying red Chakrata slates and quartzites, while to the south the upper grey slates are exposed, notwithstanding the prevailing northerly dip of the beds. This is but part of the great Himalayan puzzle, that newer beds almost always seem to dip under older, that faults are generally reversed, and that the dip of the beds in their neighbourhood is precisely the reverse of what would be expected on *à priori* grounds. The total thickness of these beds is indeterminable, partly on account of their intense disturbance, and partly from the fact that neither their base nor summit has been seen, but it must amount to many thousands of feet.

4. In northern Jaunsar there is another exposure of the same beds intersected by a great fault which, first appearing from underneath the Deoban limestone near the village of Konain, runs north-westwards to Mudhaul, on the west of the Tons, and which I shall refer to as the Konain-Mudhaul fault.

5. To the east of this fault there is exposed a great thickness of grey slates and quartzites, over which comes a band of blue limestone 300 to 400 feet thick, and over this white and coloured quartzites with interbedded red and grey slates; and near Kanda, what appear to be contemporaneous, but may be intrusive, beds of trap, overlaid by greenish slates, which last are covered unconformably by the Deoban limestone. Among the quartzites there is, near Kanda, a band of coarse quartzite conglomerate about 8 feet in thickness, which has been marked

[1] Mem. G. S. I., Vol. III, pt. 2.

on the map illustrating Colonel McMahon's paper[1] as Blaini; but the associated beds and the absence of the characteristic limestone seem to render this impossible.

6. To the west of the fault the section as seen on the ascent from Anu[2] to Bana is first white quartzites with interbedded green and grey slates, overlaid by green and grey slates without quartzites and these again are capped at Chajar (Chilar) by a small patch of blue limestone, which can hardly be anything but the same that is exposed near Kanda, and which I correlate with the Chakrata bed. The only other thing it could well be is the Deoban, but though on the upthrow side of the Konain-Mudhaul fault so far as it affects the Deoban limestone, it is at a lower elevation than the base of the latter as exposed above Banu on the eastern or downthrow side.

7. Here, whether the limestone band be identified with the Chakrata bed or no, there seems to be an inversion on one side or other of the fault, probably to the east, and it is evident that the fault must have a throw sufficient to bring the same bed on either side of the fold to about the same level; it is at present impossible to say for certain which is the up and which is the down throw side, nor to determine, even approximately, the throw of the fault, but it must certainly be measured by thousands of feet.

8. In several parts of Jaunsar volcanic beds are exposed in the Chakrata series; to the east of Chakrata, in the valleys of the Kutnu and Mord gadhs (stream), there are several beds of volcanic breccia and ash lying both above and below a thick band of blue limestone identifiable with great probability as the Chakrata band; near Lauri the same limestone again crops out and is once more associated with the volcanic beds, which are also seen in the valley of the Gamgadh.

9. In the Tons below Anu there are exposures of a brown ferruginous and dolomitic limestone, passing into crystalline ankerite in places, which I have conjecturally correlated, notwithstanding its lithological difference, with the Chakrata limestone. The volcanic beds associated with it are here far more extensively developed than I have seen elsewhere in Jaunsar and I consider that the peculiar nature of the rock is due to a contemporaneous admixture of volcanic detritus, a supposition which is supported by the facts that the southernmost of the exposures as it is traced eastwards becomes less and less ferruginous, till near its disappearance it is in parts a blue limestone little if at all more impure than the normal Chakrata limestone, and that on the western side of the Tons valley above Anu there is an exposure of presumably the same band which, while being in parts a bluish-grey limestone, is also in parts extremely ferruginous. The facts just mentioned seem to point to a centre of volcanic energy shortly to the west or south-west of the confluence of the Binalgadh with the Tons, while the volcanic beds of eastern Jaunsar were very possibly derived from a vent in what is now Tiri-Garhwal.

[1] Rec. G. S., Vol. X., 204. [This outcrop was mapped by me, not by Colonel McMahon; I only crossed the ground once, when marching with Dr. Oldham from Mussooree to Simla in 1860.—H. B. M.]

[2] Misprinted *Dan* in the map.

10. This zone of volcanic beds promises to be a horizon of great value in tracing out the geology of the Lower Himalayas, and it may not be out of place to indicate the probability of their being contemporaneous with the silurian volcanic rocks of Kashmir and the North-West Himalayas. At the same time I must point out that it is not absolutely certain that they are of the same age as the Chakrata limestone; for although the limestone with which they are associated occurs in a similar position to, and is most probably the same as, the Chakrata bed, yet it must not be forgotten that in the typical area no associated volcanic beds were seen.

11. Overlying the Chakrata series comes a great thickness of limestones and dolomites so similar to the Krol series as to be almost certainly contemporaneous with it, but which, as its relation to the underlying beds is very different to what has been described on the Simla section, I shall provisionally call the Deoban limestone. Lithologically it consists of a great thickness of bluish-grey bedded limestones, some of the beds, as on the ascent to Deoban from Chakrata, containing many nodules of chert; others which are generally mephitic have a peculiar pisolitic structure, being composed of small round black nodules cemented by a white calcareous matrix: a peculiar structure seen in some of the beds makes them resemble an accumulation of some closely-chambered shells imbedded in a matrix of calcareous mud, and so organic looking that it is difficult to believe that they are not obscured fossils. A very considerable proportion of the beds is in some of the sections dolomitic, varying from a slightly magnesian limestone to a pure pale-grey crystalline dolomite. Interstratified with these calcareous beds is a varying proportion of slaty beds, occasionally coloured, but as a rule grey.

12. This series is quite unconformable to the underlying Chakrata beds, as is proved by its unconformably overlapping or overstepping their eroded edges. This is very well seen near Konain, where the Deoban lies on the Chakrata limestone while as the boundary is traced to the west it is seen to rest successively on a (locally) descending series of slates; the unconformity is further indicated by the way in which the limestone rests, above Kanda, on the eroded edges of the presumably inverted Chakratas, and by the fact that the Konain-Mudhaul fault which, as above explained, has a throw of some thousands of feet in the older rocks, has, where it cuts the Deoban limestone, a throw of a few hundreds at most, this being due to a later movement along the original fracture; it would serve no useful purpose to describe every junction of the two series, as the same facts are everywhere to be seen.

13. It is evident that this is very different to what has been described on the Simla section,[1] and there are but three possible explanations—*1st*, that the Deoban and Krol limestones are not contemporaneous; *2nd*, that the junction on the Simla section is only apparently and locally conformable; *3rd*, that the Chakrata series is older than the Simla slates and underlies them unconformably. The first supposition may, I think, be dismissed; the second I regard as very probable, the very sudden variations in the thickness of the Krol quartzite pointing to a

[1] H. B. Medlicott: Mem. G. S. I., Vol. III., *passim*, and Manual, pp. 594-609.

possible unconformity between it and the Krol limestone; the third is also possible; but if the volcanic beds of Jaunsar are really of upper-silurian age, there is hardly room for the whole of the sequence between these upper-silurians and the (at latest) triassic Krol limestone. At present sufficient facts are not at my disposal to enable me to say which of the latter two hypotheses may prove correct, but the question depends very much on the nature and amount of the disturbance of the Chakratas anterior to the deposition of the Deoban limestone. The inversion at Kanda may have been a purely local feature, the Chakratas having been elsewhere comparatively undisturbed at the time of deposition of the Deobans—in that case the second supposition may be correct, and the Chakrata beds either representatives of, or forming part of a conformable sequence in, the rocks below the Krol; but if it should ultimately prove to be merely part of a widespread disturbance, the third hypothesis alone remains possible.

14. Above the Deoban limestone comes a series of beds mostly conglomeratic, first identified by me in the neighbourhood of the Mandhali forest bungalow, after which I propose to call them, at any rate provisionally. They consist of conglomerates mostly with a slaty matrix through which pebbles of quartzite slate or limestone are scattered, though some and in southern Jaunsar the majority of the beds are not conglomeratic at all, others are coloured slates not unlike indurated Sirmurs, and others again are calcareous; of the latter, some are fine-grained limestones, others, though this I have only seen near to Mandhali, are limestone conglomerates cemented by a limestone matrix. The presence of these pebbles derived from the underlying Deoban limestone is sufficient to stamp the beds containing them as unconformable to it. In southern Jaunsar, in addition to the limestone conglomerate with slaty matrix, which is not found in every exposure, the characteristic rock is a quartz grit containing fragments of indurated red slate derived from the lower Chakrata beds.

15. The facies of the Mandhalis is essentially littoral, or shallow water, as is testified to by their coarseness of grain, while the conglomerates with a slaty matrix, so similar to those of Blaini age, could not have been formed except through the agency of floating ice; but it is not a little remarkable that, notwithstanding their evidently shallow water origin, there is hardly an exposure which does not exhibit one or more beds of pure limestone: this association of littoral beds with limestone is well seen on the cart road to the north of Kalsi; where a thick band of limestone is bounded on both sides by coarse-grained quartz grits.

16. Outside of Jaunsar I have detected these same beds, to the east in great force near Naini Tal and Bhim Tal, and to the west, in the Giri valley, I saw in 1881 some conglomerates, which at the time puzzled me not a little, but which I cannot now hesitate to refer to Mandhali age.

17. As regards the homotaxy of the Mandhalis, they are later than the Deoban, and are evidently of earlier date than the main disturbance of the Himalayan rocks; so much so that in the limestone area of northern Jaunsar, the small patches that have been left owe their preservation entirely to having been caught up in the folds and faultings of the limestone, and in this way preserved from denudation. They consequently occupy a position analogous to that of the Sirmurs to the northwest, and at first one would be inclined to correlate them

with the last-named rocks and assign to them an early tertiary age. However, the fact that nummulitics of normal type are to be found near Rikhi Khes in Garhwal[1] taken in conjunction with the extent of the Mandhalis, is against this supposition, which, too, it is impossible to reconcile with the finding of characteristic Mandhalis in the Giri valley, within a few miles of the boundary of the Sirmurs, in which no similar rock is to be seen. They must therefore be of pre-tertiary age, for there is no room in the sequence for them to come after the Sirmurs.

18. Above the Mandhalis are two series of rocks, of which, as they occupy totally distinct areas, it is impossible to say which is the older. Of these one is the Nahan; but as it occupies a very small area in the extreme south of Jaunsar, and as it presents no peculiarities, it may be dismissed without further notice.

19. The other series merits attention, as it presents an unsolved and apparently unsolveable problem. In north-eastern Jaunsar, occupying a considerable tract of country is a series of fine-grained glassy quartzites with interbedded schists, some of the beds containing granules of blue quartz, which in the Tons descend to the level of the river, but southwards merely cap the ridges, they lie almost undisturbed and nearly horizontal on the eroded edges of the intensely disturbed older rocks, and are evidently far newer than any of the other formations in Northern Jaunsar, or Bawar as it is locally called; yet, though so much newer and so much less disturbed, the rocks are far more metamorphosed than those of the older series, the siliceous beds being everywhere converted into glassy quartzites, and the argillaceous bands being, in Bawar, uniformly schistose, while across the Tons, in Garhwal, they occasionally become almost gneissose. I propose to call this the Bawar series.

20. As the Bawars are evidently of much later date than the main disturbance of the rocks, which in the Simla section has been shown to be of post-eocene date, they would seem to be referable to a middle or upper tertiary age; but it is difficult to suppose that rocks so metamorphosed can be contemporaneous with the soft sandstones of the lower or the loose shingles of the upper Siwaliks, and besides there are very strong reasons for believing that even in Nahan times the Himalayas existed as an elevated tract subject to denudation; nor is there any similarity between the Bawar and Nahan rocks even where the latter have been metamorphosed by igneous intrusions. It is however possible that these Bawars may be of lacustrine origin and contemporaneous with the Nahans,—a supposition supported to some extent by the extremely small development of the Nahans at the debouchure of the Tons and Jamna rivers, and by the fact that the Bawars so fine grained to the south of the Tons become near their summit, in Garhwal, coarsely conglomeratic. When more information has been collected, these difficulties may doubtless be cleared up, but the improbability of ever finding any fossils in these rocks is a serious hindrance.

21. The glacial epoch has left its traces in Jaunsar, though I know of no traces of actual glaciers to the east of the Tons. Above Kistur there are what might at first sight be taken for terminal moraines, but a more detailed examination

[1] Mem. G. S. I., III, pt. 2, p. 90; and Manual, p. 585.

banishes the idea; the only deposits that can be referred to this epoch are the high-level gravels to be seen in most of the valleys but most distinctly in that of the Seligadh where, as can be seen from the Chakrata and Mussoorie road, they form broad gently-sloping terraces on the valley sides; the slope of the surface is more rapid than that of the present bed of the stream, being over 800 feet above the latter at Makhata while near the junction with the Jumna the difference in level does not exceed 100 feet; in the small lateral valleys the slope rapidly increases, so that sometimes the gravel deposits run almost up to the crest of the water-shed. These gravels have been formed since the Seli valley was cut down to its present depth, as is shown by their extending in places right down to the present level of the stream; they could not have been formed under existing circumstances, for apart from the angularity of the fragments of which they are composed and the slope of their surface the peculiar parabaloidal curve of the surface up the lateral valleys is totally different to what is now being formed anywhere in the lower-Himalayas, but could only have originated when the balance of disintegration and precipitation was very different to what is now the case; disiutegration must then have been so rapid that the streams could not dispose of the debris which was shed from the hill slopes, the valley was consequently filled by a deposit whose surface had a comparatively gentle slope in the main valley where the volume of the stream was greater, while in the lateral valleys, where the amount of debris was comparatively greater, the slope increased till it reached the angle of repose. It is needless to expatiate on the fact that this increased disintegration can under the circumstances only be attributed to a more rigorous climate, frost being the great disintegrator in these latitudes.

Notes on a Traverse through the Eastern Khasia, Jaintia, *and* North Cachar Hills *by* TOM. D. LATOUCHE, B.A., *Geological Survey of India.*

The object of my season's work was to search for coal and iron within reach of the proposed line of railway from Silchar to the Brahmaputra valley through the North Cachar hills. From what was already known of the ground (Mem. G. S., Vol. IV., pt. 3, 1865) there seemed to be little or no prospect of success, and so it has turned out.

Arriving at Cherra Poonjee about the middle of December, I spent a few days in examining the area mapped by Mr. Medlicott in 1871 (Mem. G. S., Vol. VII., p. 151) so as to familiarise myself with the rocks in it. I then marched across the Jaintia hills to the North Cachar hills, visiting the coal-field of Lakadong on the way.

1. Lailangkot to Jawai.—Leaving the village of Lailangkot, which is situated on the boundary of the Shillong series and the granite area of Molim, by the old road to Jawai, Shillong quartzites and granite are passed over alternately for the first 5 miles, there being three exposures of granite extending across the road to the south-west, and probably connected with the main area to the north. The quartzites are vertical, or dip at very high angles with a general strike from

north-east to south-west. The last exposure of granite is about 1 mile to the south-west of Rableng hill. This hill consists of Shillong rocks, which extend without a break to the Mantedu at Jawai, the strike being generally between north and north-east but bending round to east-north-east between the Mangat (the boundary of the Jaintia hills) and the Mantedu. In this direction also the rocks become more schistose, several beds of fine-grained hornblende schist occurring in the valley of the Umthungpha, about 1 mile above its junction with the Mantedu. At the top of the hill to the east of the Mangat, near the village of Simunting, is a small outlier of cretaceous rocks.

Beneath the village of Jawai the schists and quartzites are capped by patches of cretaceous conglomerates, forming low hills in and about the villages; the bedding in these is horizontal.

2. Jawai to Lakadong.—Turning south from Jawai along the Jaintiapur road, Shillong rocks extend to the summit of the hill south of the Mantedu, where they are capped by fine cretaceous sandstones forming low scarped hills on either side of the road. Near the 5th milestone from Jawai the border of a small area of granite is passed on the right-hand side of the road, extending to the south-west. The road then runs round the south flank of a hill of cretaceous sandstones to the Mankajai, in the valley of which a broad dyke of trap occurs. This is a coarsely crystalline, dark-coloured rock with a rather metallic lustre and weathering red, and is entirely composed of augite and titaniferous iron. Cretaceous sandstone again appears in the scarp to the south of this valley, coarse at the base and becoming finer towards the top. These rocks continue to and beyond Jarain, forming an undulating plateau with slight inclination to the south.

Coal at Jarain.

At Jarain coal occurs in these rocks, and has been worked to a small extent to supply the dâk bungalows here and at Jawai. A seam crops out on both sides of a gully close to a small bridge on the road to the south-east of the village, and is about 3 feet thick, overlaid by about 12 feet of hard, fine-grained sandstone. It has the usual characteristics of the cretaceous coal of these hills. Another outcrop occurs at about 1½ miles to the north-east of the village and 1 mile from the road, in a small stream running into the Um Pliang, a tributary of the Mantedu. The seam is well exposed, the stream flowing over it in a low fall. It is 2 feet 6 inches thick, with fine-grained sandstone above and below. This coal contains a good deal of pyrites in small nests, and at the base of the seam the rock is covered with a net-work of this mineral, so that the coal would be of very little value.

Turning off to the south-east from the Jaintiapur road in the direction of Lakadong, the path passes by Amlittshor village over the plateau of cretaceous rocks deeply indented on either side by tributaries of the Mantedu until the gorge of this river is reached. This gorge is here about 1,000 feet deep.[1] The cretaceous rocks extend on both sides of the gorge to about 300 feet from the top

[1] Unfortunately my aneroid was out of order, so that I was unable to measure exactly the depth of the gorges crossed in this part of the hills.

and rest directly upon metamorphic rocks, which extend on both sides to the bottom. These rocks are similar to the metamorphics found on the north slope of the hills.

From the top on the opposite side an undulating plateau of cretaceous rocks extends for about 4 miles to the village of Shushen, which is situated on the edge of the gorge of the Lauriang, about 3 miles above its junction with the Mantedu. Cretaceous rocks extend to a few hundred feet from the top on this gorge also, resting on metamorphics, and appear at the same level on the opposite side beneath the village of Batao. These rocks extend to the hill on which Lakadong stands, about half way up which nummulitic limestone occurs, overlaid by sandstone with coal.

Lakadong coal.

The coal workings here appear to be in much the same state now as at the time of Dr. Oldham's visit in 1853 (Sel. Rec. Ben. Govt., No. XIII., p. 45), as since then very little coal has been extracted. The different holes have been driven into the coal as far as is possible without having to support the roof with timber, and the expense of this, together with the increased cost of labour and of carriage to the plains, in 30 years, would probably prevent the coal being worked with profit at the present time. The headman of the village told me that 500 maunds had been extracted last year, and sent down to the plains, but he could not tell me what the cost of extraction and carriage was.

3. Lakadong to Nokhara.—To the north of Lakadong on the path to Umrasiang cretaceous rocks forming low scarped hills extend to the gorge of the Saichampa, about half way down which metamorphic rocks appear and a similar section is seen on the opposite bank. The lowest cretaceous beds here are ferruginous sandy clays. Close to Umrasiang village I observed a circular pit, with perpendicular sides in the sandstones, 50 or 60 feet deep, and as many in diameter, probably due to the washing away of the clays beneath through a fissure and the consequent falling in of the sandstones above. The cretaceous rocks continue to a hill about 2 miles east of Umrasiang, near the top of which nummulitic limestone forms a steep scarp to the north. This hill is flat-topped, consisting of sandstones similar to those at Lakadong, but without any traces of coal till near the village of Nokhara, where there is a seam 1 foot thick resting on carbonaceous shale, but of no great extent. To the south the ground falls gradually to the edge of the streams running into the Lubah, where limestone again appears. In many places near Nokhara I noticed large funnel-shaped hollows, 20 or 40 feet deep, caused by underground denudation of the limestone.

4. Nokhara to Kampat.—Proceeding to the north from Nokhara on the path to Satunga after descending the limestone scarps to the north, a small outlier of limestone is passed near the village of Umluper. To the north of this the plateau is much more broken than to the west as far as the Laterkap river, in the gorge of which metamorphic rocks occur again. Near the village of Nongtomá (not marked on the map, but about 2 miles to the south of the Laterkap) I passed a funnel-shaped hollow similar to those at Nokhara, but could not find any limestone below it. To the north of the Laterkap cretaceous rocks extend without a break to Satunga, where they contain a seam of coal.

Coal at Satunga.

Its outcrop is seen at the head of a small ravine to the north of the village. A vertical section, in descending order, is as follows:—

	Ft.	In.
Sandstone and shale, about	20	
Coal	1	9
Shale, carbonaceous at top, less so towards the bottom	5	
	26	9

The hill side slopes rapidly upwards from the top of the section.

Two outliers of nummulitic limestone occur a short distance to the west of Satunga. To the east the ground slopes downwards for about 4 miles to the village of Kampat, which lies at the foot of a well-defined ridge running north and south. The lower 300 feet of this are nummulitic limestone, with a slight dip to the east, resting on a wavy surface of cretaceous rocks, and extending to north and south as far as one can see.

This is capped by upper tertiary sandstones resting on the limestones, and extending to the top of the ridge 500 feet above Kampat. These rocks, though they occupy the same position with regard to the limestone as the coal-bearing rocks of Lakadong and Nokhara, do not contain any traces of that mineral, nor is it found further to the east. They are fine-grained, highly ferruginous sandstones, the lower beds containing numerous grains of pisolitic iron ore. The sandstones rest conformably on the limestone, though in places there are local unconformities, due to underground denudation of the limestone. According to Colonel Godwin-Austen these rocks contain numerous minute fossils. From the top the ridge is seen to bend round to the north-east, striking for the Kopili. A vertical section of the ridge is as follows, in descending order:—

		Ft.	Ft.
Upper tertiary.	Fine-grained ferruginous sandstones, with a little pisolitic iron ore near the base, about		200
Nummulitic limestone.	Massive limestone, becoming shaly and earthy towards the top, about	70	
	Massive limestone, shaly and earthy at top . .	160	
	Thin bedded earthy limestone	70	
			300
			500

On the eastern side of the ridge limestone is met with again at about 230 feet from the base, and continues to the level of the valley in which Nonklir stands. This is a flat, alluvial plain about 2 miles broad at this part. From the top of the ridge the limestone is seen to form a fringe at the base of the hills surrounding the valley, extending to the south as far as the base of Jakorsing hill, the boundary between the limestone and upper tertiaries being easily traced, as the former is covered with thick tree jungle while the sandstones above are nearly bare of trees and covered with grass.

The limestone visible at the base of the ridge to the east of Nongkli is reduced to 130 feet in thickness, and is succeeded by upper tertiary sandstones and shales rising to 550 feet above the valley. In the next valley to the east limestone does not appear, nor is it again found anywhere to the east.

5. Kampat to the Hot Springs on the Kopili.—Following the limestone to the north from Kampat, it is found to occupy nearly the whole of the space between the Kharkor and Kopili rivers, cretaceous rocks forming a fringe at the base of the limestone scarp. It is capped by upper tertiary sandstones beneath the village of Pala, which is situated on a spur of Pomlana 3,754 feet above sea level. To the west of the Kharkor are numerous scarped outliers of limestone, the largest overlooking a level plain of cretaceous rocks to the north of Muncha river. This plain extends to the foot of a lofty ridge of metamorphic rocks (on which the village of Khaushinong stands) running north-east to the Kopili. The metamorphics cross the Kopili about 1 mile north of the hot springs and form the ridge running east and west, called Khandong hill. The Kopili forms a succession of very fine falls and rapids over these rocks.

The nummulitic limestone crosses the Kopili to the north of Umkerpong, and bends round to the east parallel with the metamorphics of Khandong hill. It extends to the east as far as the flanks of Phulong hill, but it does not appear in the valley of the Diyong still further to the east.

The valley between it and the metamorphics is occupied by cretaceous rocks, except at the hot springs, where a small area of limestones has been let down by faults among the cretaceous beds.

6. The hot springs.—The following notice of the hot springs is given in Dr. Oldham's catalogue of the thermal springs of India (M. G. S., Vol. XIX, pt. 2, p. 54):

"KOPILI.—Latitude 25° 31′; Longitude 92° 40′; Temperature 122°.

"On the right bank of the Kopili, three days' journey from Silchar, one and a half day's journey from Jawai. The water is not saline but only hot. Official Returns.—Captain (now Lieutenant-Colonel) Godwin-Austen, however, speaking of the spring in a private letter, says it is strongly saline."

The distances given above are not quite accurate as the spring is at least seven days' journey from Silchar and two from Jawai. There are three springs lying in transverse gullies on either side of a stream running west into the Kopili, and about 100 yards from the latter. Of these the one to the south is considerably larger than the other two. Its temperature I found to be 128°. The water had not the slightest saline taste, or indeed a taste of any kind, rather resembling distilled water. The temperature of the two small springs to the north was 130°, and this water also was perfectly tasteless. All these springs lie on the faulted boundary between the cretaceous and nummulitic rocks. The stones over which the water runs are covered with a very thin white deposit, probably calcareous. That this deposit is not thicker, is probably due to the fact that the Kopili during the rains rises several feet above the level of the springs, and so washes it away.

7. Upper Tertiaries of the North Cachar Hills.—Beyond the limestone ridge to the south-east of the hot springs upper tertiary rocks extend in an unbroken mass to the Barail range above Asalu. As far as the police outpost of Gunjong these rocks are horizontal, or nearly so, consisting of fine-grained sandstones and shales. It is in the valley of the Mahur, to the east of Gunjong, that the change from the generally undisturbed condition of the newer rocks on the Shillong plateau takes place, the upper tertiary rocks to the east being everywhere greatly disturbed. The transition does not take place so abruptly as on the southern edge of the plateau, where the newer rocks are bent down suddenly in a uniclinal curve into the area of disturbance; but it is well marked, the rocks at Gunjong having a slight inclination to the east, while in the Mahur valley they are sharply contorted and at Quilong on the opposite side are nearly vertical. The boundary between the disturbed and undisturbed sweeps round to the west, along the Jatinga and Lubah valleys, until it coincides with the east and west strike of the edge of the Shillong plateau.

In these beds, in the Mahur valley, I found a few insignificant strings of coal, but no where did I come across any workable quantity.

Quilong limestone.

Before leaving Calcutta in November I had heard that there were considerable deposits of limestone near the outpost of Quilong, and while there I went in search of them They are situated on a small stream running into the Langting, to the north-east of Quilong, and about 1,500 feet below it. The rocks here are shales dipping at 20° to north-north-west, and the stream has deposited a bed of calcareous tufa on the upturned edges of the shales. This limestone is from 1 to 2 feet thick where thickest, and is of small extent. A small quantity was burnt on the spot several years ago when the outpost at Asalu was being built, and the remains of it, which are still used to supply Quilong and Gunjong with whitewash, are to be seen in the jungle close by. Similar deposits also occur in the valleys near Gunjong, but none has been burnt there.

Iron.

The natives on the northern border of these hills informed me that in former times they used to extract iron from a highly ferruginous drift which is found in most of the hill streams. But the manufacture of it has entirely died out, and at Walsalai a large Kuki village to the east of the Dirjung, I found them making implements with iron brought from Calcutta.

The iron ore deposits are very scattered, and would probably not repay systematic working.

On Native Lead *from* Maulmain, *and* Chromite *from the* Andaman Islands; *by* F. R. MALLET, *Deputy Superintendent, Geological Survey of India.*

Native lead.—Amongst a number of ores from the neighbourhood of Maulmain, in Burma, lately sent to the Geological Survey Office by Mr. G. H. Law, is one of a somewhat unusual character. It is a carbonate of lead, breaking with a rather largely facetted crystalline fracture, and having a bright red colour due, apparently, to an intimate admixture of minium. The mineral contains small cavities lined by minute white crystals of ordinary cerussite, and some of the cavities are partly filled with metallic lead. The above-mentioned substance has the appearance of a natural product, but the precaution was taken of writing to Mr. Law on this point, and in reply he states that it is "natural and not artificial." As native lead is a mineral of rare occurrence, its discovery in a new locality is worth putting on record.

Red carbonate of lead similar to the above, except that the native metal has not been observed in association with it, has been found also in the Hazáribágh district of Chutia Nágpur.[1]

Chromite.—During the present month a block of ore was to be sent to the Geological Survey Office, for examination, from the Officiating Chief Commissioner of the Andaman and Nicobar Islands. Mr. M. V. Portman, Extra Assistant Superintendent, who visited the place where it was found, writes: "About 100 yards south of the village of Chuckergaon, on the bank of a small stream, was a mass of ore about 9 inches thick and 4 feet long. It was lying on the surface of the ground. On removing it, and digging round and underneath it, the rock appeared to be a coarse sandstone strongly impregnated with iron. No more ore was found on this spot, though it again appears in two places further down the valley in some considerable quantity, several hundredweight having been brought in. On examination of the rocks within a radius of 300 yards, I found granular and highly crystalline limestone, intersected by views of calcspar in some instances 4 inches thick, diorite, porphyritic trap, and coarse ferruginous sandstone." Chuckergaon, the village mentioned, appears to be close to Port Blair.

The ore proved on examination to be chromite. As this mineral is usually found in serpentine, and serpentine is known to occur in the neighbourhood of Port Blair, there is a strong probability that the Andamanese chromite is no exception to the general rule. "Serpentine and gabbro are found largely developed south of Port Blair and on Rutland Island, and are doubtless intrusive. A "micro-crystalline syenite" was noticed in one locality by Mr. Kurz; it is doubtless a form of the dioritic rock found locally associated with the serpentine in Pegu.[2]" It will have been remarked that Mr. Portman observed diorite, &c., close to the place where the chromite was found.

As chrome iron ore (chromite), of average quality, is worth about £10 a ton in England, the Port Blair mineral, if obtainable in considerable quantities, is well worth attention.

Notice of a Fiery Eruption *from one of the* Mud Volcanoes *of* Cheduba Island, Arakán.

The following correspondence respecting an eruption from one of the Cheduba mud volcanoes is published in continuation of similar records[3]:—

F. R. MALLET.

From Captain F. D. RAIKES, *Deputy Commissioner, Kyouk Phyoo, to the Commissioner of Arakán, Akyab, dated Kyouk Phyoo, 2nd May 1883.*

I have the honour to forward a free translation of a letter received from the Myooke of Cheduba, in which he reports that the volcano in the Minbyin Circle of his Township gave

[1] Records, G. S. I., Vol. VII. p. 35.

[2] W. T. Blanford, Manual of the Geology of India, part 2, p. 733.

[3] *Supra*, Vol. XI, p. 188; XII, 70; XIII, 206; XIV, 196; XV, 141.

out flames on the 23rd March last. The Myooke's report is dated 23rd April, and was received here yesterday. I am about to start for Cheduba, and should anything new regarding the volcano be ascertained, a further report on the subject will be submitted.

From MOUNG TSAU OO, *Myooke of Cheduba, to the Deputy Commissioner, Kyouk Phyoo.*

I beg to report that having been informed that there was an eruption of the volcano in the Minbyin Circle of this Township on the 23rd March last, I sent the following questions to Moung Wine, Yuawoot Gonug of Minbyin, for answer His answers are given against each question :—

Question.	*Answer.*
1. Did the eruption burst out violently? ...	The eruption was sudden and violent, gradually subsiding.
2. Was it gradual? ...	
3. To what height did the flames rise? ...	About 800 feet (*sic*).
4. What was the circumference of the flame?	About 450 feet.
5. How long did the eruption last? ...	About 9 minutes.
6. Did the flames give out any smell? ...	Yes, that of earth oil.
7. Was there much smoke? ...	Little smoke in comparison with the flame.
8. Was mud alone thrown out? ...	Mud and gravel, no other mineral.

NOTICE.

Irrigation from wells in the North-Western Provinces and Oudh, by CAPTAIN J. CLIBBORN, B.S.C., *Executive Engineer, on Special Duty, Department of Agriculture and Commerce, N.-W. P. and Oudh.* In the Professional Papers on Indian Engineering, 3rd series, Vol. I, p. 103, Roorkee, 1883.

1. In all the visible and measurable elements of the investigation undertaken by Captain Clibborn, the method adopted seems to have been thorough, and the results obtained must be of great and permanent practical service. By the adoption of a unit of work, with values determined by careful experiment, he has reduced to comparable form a chaos of information upon the subject in hand with reference to the depths and capacities of wells and the processes of 'lift' in use. He has moreover applied his method over an immense field of observation, extending right across the Gangetic plains from the terai on the north to the Vindhyan scarp on the south, and some 250 miles broad between Agra and Fyzabad. The sound facts thus accumulated must indeed be accepted as a main contribution to the question in view; but there are considerations of fundamental rather than of collateral importance regarding the distribution and the supply of water available, upon which much light might have been expected from such a course of observation, and upon which the remarks offered by Captain Clibborn are not only defective but misleading; because, no doubt, the facts concerned are not quite visible or measurable. This branch of the subject has come within the cognizance of the Geological Survey, so that some notice of the matter is here called for.

2. The question of artesian sources in the plains of India has been discussed at some length in these Records (Vol. XIV, page 223, *et seq.*), and the probability

of their occurrence asserted. In the paper under notice, Captain Clibborn professes to show that artesian action is quite incompatible with the strata of the Doab. It is necessary to quote two paragraphs to make the position clear :—

"22. Leaving out of the question for the present wells which receive a supply from percolation, we will consider the case of what are usually termed spring (*bom*) wells, which should be sunk so as to have the end or lower ring firmly imbedded in the *mota* (layer of clay), thereby (if a masonry well) shutting out from direct entry all water overlying it. Now the generally adopted theory regarding the use of the mota for water supply is that it acts as an artesian basin, and that the supply entering the well through an orifice which is bored in the clay is a veritable spring, caused by the pressure of water from the collecting area of the basin.

"23. The facts which are alleged to support this theory are *first*, that until the mota is reached, the water-supply is easily exhausted. This is contradicted by experience. *Secondly*, that when the hole is bored into the mota a copious supply enters the well, often causing danger to the workmen if they do not escape quickly, and sometimes rising above the mouth. But the artesian theory pre-supposes the comparative continuity of the mota, which is at variance with the universal testimony of cultivators, and the facts alleged are easily explained on other grounds, *vide* paras. 26—30. It will also be shown that artesian action is quite incompatible with the strata of the Doab."

3. This last sentence is a general proposition, and would properly be taken to include the whole formation concerned. We are by no means sure that Captain Clibborn does not intend it in this sense, for the strata at greater depths are no doubt of the same pattern as those exposed; but as the facts immediately quoted (paras. 24-25) regarding the contour of the sub-soil water (although they are somewhat irrelative to the immediate question) can only refer to the ground above the level of the rivers, and as no direct allusion is made to deeper artesian springs, we may restrict the discussion to the narrower issue; and upon this it is not difficult to show that Captain Clibborn does not seem to understand the needful conditions of evidence or of argument. We are by no means concerned to prove that the *bom*-wells are artesian; only, if the facts asserted of them are correct, they are essentially of that nature.

4. The first fact refuted by Captain Clibborn, in his paragraph 23 just quoted, may be said to be irrelative; but even upon the theory he himself adopts it is not easy to see how experience can contradict that a deeper well, tapping a larger segment of the same water basin, is less easily exhausted than a shallower one. For the 'alleged fact' of the water rising above the surface Captain Clibborn would have done well to introduce the plain contradiction argument, as it would be impossible to explain it otherwise than as artesian; and we need hardly say that no attempt is made to do so. For the remaining and essential point, that water does rise from below the clay, Captain Clibborn adopts a double course, to vitiate the opposite view and to offer a simpler explanation; but in both lines of argument he begs the point at issue.

5. It may well be true that the clay band is not everywhere continuous; but it is altogether too dry a statement to say that the artesian theory pre-supposes this continuity, though such an impression would readily be conveyed by the ordinary text-book exposition of artesian conditions, dealing with strongly-marked examples. Partial artesian action is always possible when percolation along the planes of bedding is much more easy than across them, and this seems to be a general

character of stratification independently of any visible impervious beds. In anticipation of objections such as this, when the proposal for artesian borings in Upper India were first brought forward (in 1867), instances were quoted showing the compatibility of artesian springs with great irregularities (want of continuity) of the deposits (Selections, Government of India, Home Department, No. CLXXVIII, p. 48. 1881.) This condition then, as framed by Captain Clibborn, is artificial.

6. The first item in the housewife's receipt for hare soup, beginning with the injunction to catch your hare, is of equal importance in discussion—to fix your fact before beginning to talk about it. When the *bom*-wells were quoted as an apparent instance of partial artesian action, it was assumed that the engineer who described the phenomenon was aware of the fact that if a tube with a diaphragm over the end be depressed into water the fluid will rise to the same level inside when the diaphragm is pierced; also, that in bringing the fact of the well to notice he was satisfied it was not an instance of this familiar experience, that in fact the waters above and below the clay did not stand at the same level, and were distinct, of which indeed he did give strong independent evidence in the wholly different nature of the water above and below the clay, and this is really the essential question at issue—whether or not the two water strata are distinct. It appears however that Captain Clibborn has an equally implicit conviction on the other side, for he decides the point with a simple assertion (paragraph 27), "the head is the difference of level between the water inside and outside the well;" and he seems to think that the only evidence needed on this score is to show how the water would perform the passage, the fact of free communication between the water tables having been assumed. This is the 'explanation on other grounds,' for which we were referred to paragraphs 26—30. It is introduced as 'a theory, advanced by Mr. J. S. Beresford, Executive Engineer, Irrigation Department,' and consists of an exposition, with the aid of numerous diagrams, how when sand is forced up with the water from below through a hole in the bed of clay, a hollow must be formed in the place vacated by the sand, and further how in passing from the upper to the lower stratum the water will obey the laws of mechanics. It is all quite beautiful in its simplicity, not excepting the omission of the one thing needful, even as a blank assertion, that the natural water levels of the two strata are constantly one and the same. Upon this crucial point (which would have set the whole matter at rest) one would think Captain Clibborn might have picked up some information during his extensive exploration, either by direct observation (not a very difficult matter), or 'from the universal testimony of the cultivators;' without it his 'theory' is all in the air.

7. This question of the artesian character of the bom-wells is a trivial matter in itself, having little or no bearing upon the existence of deep artesian springs, and it would hardly have deserved notice here but that the essential feature of it—the independence of the water tables—is of much practical importance on several counts, and has received notice in these pages (Vol. XIII, p. 273) in connection with the reh scourge. In that discussion, in which the Irrigation Department is deeply implicated, the more or less complete and permanent sepa-

ration over very large areas of the parasitic water (as the French call it) of the sub-soil and the deeper ground water, has passed without challenge as an admitted fact, presumably on the experience of the engineers and the universal testimony of the cultivators; and one might have thought that the investigation of the range of such conditions would have been an express object of Captain Clibborn's researches. It is clear that this fact (if it be one) of the lower water being sweet, while the upper is saline, would afford an independent and sufficient proof of the separation of the water tables and of the so far artesian nature of any rise of water from below the clay; but it is not included in the facts bearing on this point noticed by Captain Clibborn, though it certainly has been alleged in that connection. This might be an oversight; but it is not intelligible how such a fact (or statement, if it be not a fact) can have escaped prominent mention in connection with the investigation under notice, which included extensive tracts of reh land; yet it is not even alluded to. Can Captain Clibborn have found it out to be a popular delusion? His explanation of the bom-well performance would certainly imply that it is not a fact.

8. That the notion of the extensive occurrence of an impure sub-soil water permanently separated by clay beds from the ground water is not quite exploded, may be gathered from an excellent Report on Reh Swamp and Drainage, by Mr. E. E. Oliver, in the same number of the Professional Papers, where quotation is made (p. 9) of a description of such conditions in connection with reh land. The same is described from actual observation over a large part of the Doab in an early notice of the *bom*-wells in the 'Correspondence relating to the deterioration of lands' (Selections, Government of India, P. W. D., No. XLII, 1864, p. 94).

9. Having mentioned Mr. Oliver's paper, we may venture to notice what might be thought a slight confusion in the presentation of the theoretical aspect of the question, in Sections IV, *Chemical composition and analysis*, and V, *Physical theories advanced;* and confusion on this side is at the bottom of most practical mistakes, leading often to incalculable waste of effort and of money. It is rather under the latter of the above sections that one would look for an account of the origin of reh, yet the only explicit statement on this most important point appears casually in the opening sentence of Section IV, and the hints given of it in Section V are extremely obscure. The simple performance which results in a crop of reh scarcely deserves to be condemned under that much abused word 'theory,' it is so obvious when witnessed. Though unacquainted with the word 'capillarity,' any cultivator probably has a sound proximate notion of the reh crop, how it is connected with poisonous sub-soil water which the sun sucks up leaving the reh on the surface; he knows well too that the bad water would not be there if it could get away, and what prevents it. So far General Strachey's 'physical theory,' which Mr. Oliver quotes with approbation, could not well help being 'lucid'; but it professed to be "quite sufficient to account for the whole thing" (Selections, *l.c.* p 57), and as such it is probably the most hazy thing General Strachey ever wrote. Even the few sentences quoted by Mr. Oliver are rendered mischievous by the false conception they imply regarding the origin (or no origin) of the reh—that these salts are in the soil and

have been there always, having come with the silt from the mountains. He even goes out of his way to make the question occult by the interference of segregation, as in the production of flints in the chalk, saying "so too it seems highly probable that from some physical cause the sulphate of soda, &c., have accumulated in certain places on the alluvial deposits of Upper India." Yet this was written in 1864.

10. In conclusion we may point out a slight misconception where Mr. Oliver notices (p. 10) an apparent contradiction or qualification of opinion as expressed in the following quotations from Mr. Medlicott's reports—"As far as the facts before me are a guide, I am inclined to the opinion that the canal water is *the chief* source of the salt. I am now speaking of the lands newly affected" (1862); and "that the reh scourge existed widely before the canals were thought of, and *this reh constitutes immensely the greater part of what has now to be dealt with*" (1878). In the first place, the two statements pointedly refer to different ground, new and old reh land; but even if they referred to the same area the statements are not logically comparable and might have been written consecutively at either period without discrepancy, for they explicitly refer to different things, one to the stock of reh in hand, the other to the source of reh. A man might surely have little cash in his pockets though having a large income, or *vice versâ*. As a general statement, however, the first one was somewhat misleading, although in some land the possible sources of fresh reh would certainly be less than in the irrigation water. The exaggeration of the partial statement was provoked by the dogma then universally accepted that the canal water acted solely as a vehicle.

H. B. MEDLICOTT.

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